STEERING

PART 2: The Hydraulic Option

Speccing, installing, and maintaining these versatile and reliable steering systems.

Text and photographs by Steve D'Antonio

Above—*This well-engineered and -installed hydraulic steering system includes an autopilot (evidenced by its rudder-angle indicator), tightly fitted tiller arms, and stout adjustable rudder stops.*

Hydraulic steering systems operate on simple and easily understood principles. The helm is attached to a hydraulic pump, which usually incorporates a set of checking ball valves and a spool. When the wheel is turned, the pump sends fluid down one of two hydraulic lines to a hydraulic cylinder-piston arrangement. In the case of a balanced cylinder, the addition of fluid to the cylinder increases the volume to one chamber, causing the piston to extend, which acts upon the tiller arm attached to the rudderstock, causing the vessel to turn. When the wheel is turned in the opposite direction, fluid is sent down the other hydraulic line to the corresponding chamber, causing the piston to retract, drawing the tiller arm in the opposite direction.

Other configurations comprise sets of unbalanced cylinders acting on a single tiller arm and sets of balanced cylinders acting on twin rudders;

Unlike a nonpressurized unit, a pressurized fluid reservoir for a hydraulic steering system needn't be the highest point in the line, but it should be fitted with a pressure gauge and a Schrader valve to allow for pressure monitoring and adjustment.

however, the principles and results remain the same. Variations include the use of a reservoir, pressurized in some cases. Reservoirs in hydraulic systems primarily offer a reserve of fluid in the event of a leak, but they also allow air to escape from the system (air bubbles in a hydraulic system can cause spongy or even nonresponsive steering). Conventional reservoirs, most of which are contained within the helm pump itself, must be the highest component in the system to ensure that air can escape through the vent. For systems with two steering stations, the higher unit becomes the vented reservoir, while the lower one should be fitted with an unvented cap.

If the helm pump is not easily accessible, a remote, higher reservoir may be used. Some reservoirs improve on this model by adding pressure to the reserve tank. These are identified by a small pressure gauge and a Schrader valve (like those used on an automobile tire) located atop the tank. The pressurization has no effect on steering effort; instead, it prevents air from entering the system. If there's a leak, the air pressure header at the top of the tank will force fluid out—rather than allowing air to be drawn into the system—where it will hopefully be noticed before the reservoir runs dry. A desirable characteristic of a pressurized reservoir is that it doesn't need to be the highest point in the system; some are located beneath the helm, while others are adjacent to the hydraulic ram(s) and rudder(s). Wherever a remote reservoir is located, pressurized or not, it must be accessible for inspection, service, and the addition of fluid and/or air pressure.

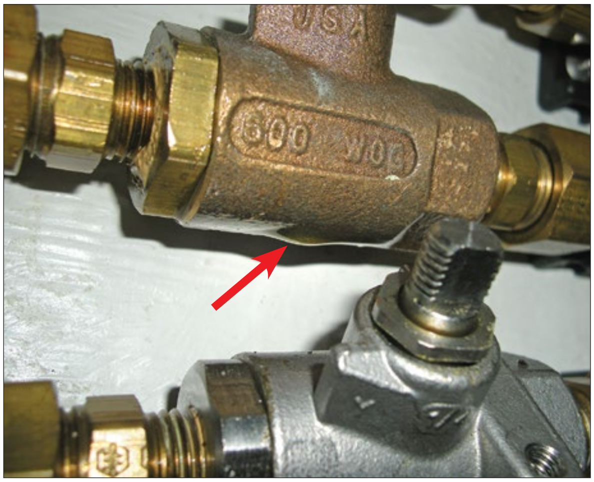
Pros and Cons

For most boats hydraulic steering has some advantages over conventional cable-over-sheave or other mechanical systems (see "Steering, Part 1" in *Professional BoatBuilder* No. 174). When the system is properly engineered, installed, and maintained, hydraulics have a proven record of being rugged and reliable in extremely harsh environments. Today, everything from nuclear submarines to mud-encrusted earth-moving equipment bristles with hydraulic pumps, cylinders, and hoses. With no cables or sheaves to chafe, wear, or break, hydraulic lines do not require clear, straight runs, which eases installation. A hose or metallic tube can be installed where a moving cable cannot.

Hydraulic systems offer the easy addition of a second (or more) steering station—in the cabin of a sailing vessel or in the cockpit or flying bridge of a power vessel, for instance. Hydraulics also interface well with autopilots, requiring only a hydraulic pump with no need for an additional tiller arm. Remember, however, any accessory such as an autopilot pump plumbed into a hydraulic steering line must have a set of service/isolation valves *rated for the system's full working pressure, which for most manual systems is 1,000 psi (69 bar) or greater.* Only steel or stainless-steel valves carry this pressure rating; no bronze or brass valve I've encountered is rated for this application.

Power assistance is sometimes added to these systems for larger, heavier vessels. Using a dedicated pump, which is

This robust hydraulic-steering installation has an upper bearing supporting the rudderstock, and twin autopilots for redundancy and easy switching should one fail.



Left—*The slight bulge of fluid hanging from the bronze valve reveals its inadequacy: it is not rated for 1,000 psi (69 bar), as required. Primarily, steel or stainless-steel models are rated for this pressure.* ***Right***—*In this installation the cast T-fittings are not rated for steering-system pressure, and there are no isolation valves between the autopilot and the primary steering hydraulics.*

typically driven by an engine power takeoff, or PTO, or in some cases via an electric motor, a small cylinder piggy-backed to the larger actuating cylinder senses effort from the helm and allows pressurized fluid to flow, so the rudder can move with fingertip effort. While these systems work well, most add complexity with the need for a raw-water source and a heat exchanger for fluid cooling, along with a pressurized reservoir. Though often secured out of sight and out of mind to outboard engineroom stringers, heat exchangers require cleaning, and the anode must be replaced. If neglected, they can develop leaks, pumping hydraulic fluid overboard with the cooling water, and allowing cooling seawater to migrate into the hydraulic system. As with engine- and generator-cooling systems, regular inspection and maintenance are key.

The disadvantages of hydraulic steering are few. Primarily and undeniably, hydraulics are not easily jury-rigged or repaired, and experienced service personnel are hard to find. However, because hydraulics are found almost everywhere in the world, nonmarine hoses and parts are often readily available. Although hydraulic systems don't often require repair, when they do, they almost always need a few specialized parts. For far-ranging vessels with hydraulic steering, some spares should be carried, along with a supply of fluid.

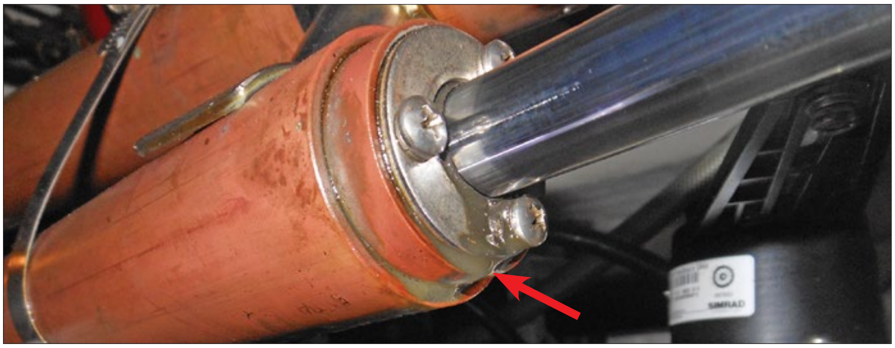
Electro-hydraulic, often referred to as fly-by-wire, is a variation of the hydraulic steering system that adds electricity to the mix. The helm(s)—almost any number can be used—are purely electronic, sending signals to an electrically driven pump, which in turn acts on the cylinder not unlike an autopilot. These systems have a conventional hydraulic-like feel to the wheel, albeit a power-assisted one. Because the helm's connection to the pump, which is adjacent to the rudders, is small-gauge wiring rather than liquid-filled pipes or hoses, installation is simplified.

Maintenance and Longevity

Especially for vessels voyaging offshore or to remote locations, maintenance and longevity considerations go hand in hand. A well-maintained hydraulic steering system, *provided it is properly designed, engineered, and installed,* is typically quite reliable. Failures are nearly always a result of incorrect installation, application of inappropriate materials, or infrequent predictive/preventive maintenance.

The primary maintenance consideration for a steering system is the condition of the hydraulic fluid. Unlike lubricating oils used in internal-combustion engines, hydraulic steering fluid is not subject to combustion byproducts, so if the system remains closed and clean, the fluid should not require replacement for years. However, if the system is contaminated with dirt, water, or debris from failed components such as hose or metal, failures usually follow close behind. The best defense is to use only the fluid specified by the steering system manufacturer and to flush and clean a contaminated system.

If the system is power-assisted via an engine-driven PTO or electric pump, at least annual fluid analysis is



The drip of fluid hanging from this hydraulic ram below the piston indicates that the seal inside is damaged. A spare ram visible above the leaking unit is permanently installed in this system, making for easy replacement while under way.

cheap insurance. Fluid specifications usually call for high-quality hydraulic oil, readily available in many parts of the world. In an emergency, some system manufacturers specify automatic transmission fluid and, in some cases, lightweight motor oil. If fluid of the incorrect *viscosity* is used, the result is usually no more dramatic than cavitation and poor performance. However, if the wrong *type* of oil is used, far worse problems could occur, such as leakage and system failure.

Other maintenance includes a close inspection of articulating piston ram ends, all system fasteners and clevis pins, seals, and the polished surface of the piston on which the seals ride. The slightest scratch or score in this surface could cause a leak. If a seal is leaking due to a damaged piston, replacing the seal will stem the leak only temporarily. The irregular piston surface will quickly damage the new seal as well.

Spares

The well-stocked spares locker for a far-ranging boat should include spare seals (which will deteriorate in storage, so inspect them annually and renew when necessary) for the piston(s)—both ends if equipped with balanced units—and spare fittings for hydraulic line, be it copper, armored hydraulic, or nylon tubing. For a system utilizing one of the latter two, a vessel should also carry the installation mandrels and necessary assembly tools, along with generous lengths of hose or tubing. Even in systems using all copper or other metallic tubing, the plumbing must use lengths of flexible hose to

This flawed installation includes nickel-plated brass valves that are not adequately pressure rated. Also, to prevent flexing and eventual failure, the transitions between the copper pipes and flexible hose should be immobilized at the hose.

connect rigid portions to the moving hydraulic cylinder. (It's critical that metallic tubing be completely immobilized where the transition to hose is made; any flexing will eventually lead to failure.)

For ultimate preparedness, carry a spare helm pump. While it's usually the most expensive part of the system, it's also the most difficult to repair without a hydraulic technician on hand. In PTO-powered systems, if the pump or plumbing fails, the repairer should be able to remove the pump from the engine or transmission and temporarily cover the opening with a blanking plate to keep the engine operating (steering with a jury-rigged steering system). These pumps cannot be allowed to turn without fluid to cool and lubricate them. Finally, for disassembling hydraulic cylinders that have circular indentations or holes in their end caps, a special spanner wrench is required. The alternative, using locking or slip-joint pliers, often distorts the cap, making leaks likely.

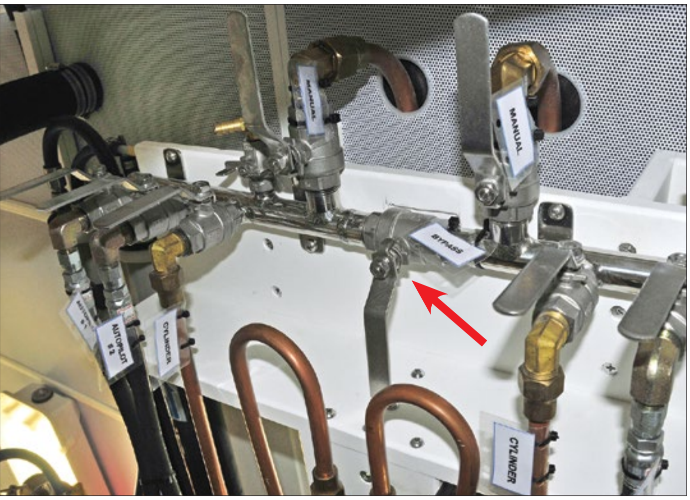
Retrofits

To install hydraulic steering where none existed before, familiarize yourself with manufacturer specifications. For offshore vessels, my rule is to find the size helm pump and piston called for by the manufacturer, and then go up one size.

One common failure in original equipment and in retrofits is the piston attachment. The repetitive, reversing, and momentary loads on this component are tremendous, so the interface between the piston and the hull must be rugged, if not overbuilt. For FRP vessels, this attachment point calls for grinding and structurally tabbed-in solid fiberglass or stainless-steel components, solid structural fiberglass sheet, angle and/or box sections, or, as an alternative, a completely fiberglass-encapsulated timber structure. All attachment points should be through-bolted rather than lag-screwed, and substantially supported with welded gussets in metal alloy vessels. No movement should be visible in the ram-support structures when sea-trialed and heavily loaded with a series of hard-over to hard-over turns.

This is the area I have seen fail most often on retrofit *and* production hydraulic-steering systems. *Heavily built* are the words that should describe these components. In addition, for most systems manufacturers, the piston doubles as a rudder stop. Conventional heavy-duty rudder stops may still be installed and would be effective if a steering component failed,

Above—*Emergency tillers should be easy to access and fit snugly to the rudderstock. This one installs handily but is a bit short for practical steering.* ***Facing page***—*Essential to emergency tiller use is the bypass valve (red arrow) that lets fluid circulate in a failed or compromised hydraulic system while allowing the piston to dampen motion.*



to prevent the rudder from striking the hull or propeller; however, in normal use, the rudder tiller arm or other components should not make contact with them. Confirm the required rudder stop protocol with the manufacturer of the hydraulic system you are using or intend to use. For *nonhydraulic* steering systems, rudder stops take on a primary rudder-swing-limiting role.

Follow the manufacturer's installation instructions to the letter, and submitting your installation plan to the manufacturer is also a good approach. If possible, avoid high spots in hydraulic lines, which trap air, and install a bypass valve or quick-release pin on the hydraulic ram so an emergency tiller can be used if the system should fail. A bypass valve is preferred because it allows the piston to dampen movement and remain in place as a stop. (If the system includes no rudder stops, the piston should *not* be disconnected from the tiller arm in the event of a failure.) If you fail to include a bypass valve or quick-release pin, a system malfunction could lock the rudder, forcing someone to disassemble the piston-tiller-arm connection in some other way, possibly in a hurry.

Hydraulics for Heavy Weather

Hydraulic steering systems are standard equipment on many offshore vessels. On those exceeding 50′ (15.2m) long, hydraulics become a veritable necessity, as cable over sheave in vessels this size becomes impractical. Because many larger vessels are offshore passagemakers, they experience more heavy weather. For properly engineered and installed hydraulic systems, this presents little if any difficulty.

Dodge Morgan sailed *American Promise*, a 60′ (18.3m) Ted Hood sloop, on a record-setting 150-day solo circumnavigation in 1985–86, much of it through the Southern Ocean, with nary a problem in her completely hydraulic steering system. I, too, have sailed thousands of miles aboard *American Promise*, when she was operated by the U.S. Naval Academy as a sail- and navigation-training vessel. While her steering system suffered a few teething problems (due to some initial design miscalculations) when new, with basic, routine maintenance, the same system, more than 20 years and many thousands of sea miles later, reliably served the U.S. Navy during regular offshore passages. On many other offshore passages in conditions often far from benign, aboard 60′–70′ motoryachts equipped with hydraulic steering, I've experienced no major failure. For systems properly sized for a boat's weight and typical operating conditions (heavy-weather-bound vessels may require hydraulic systems larger than the manufacturer's *minimum* recommendations), failure is rare. When it comes, it is most often due to neglect and inattentiveness. Chafed hoses and worn seals and clevis pins are often noticeable in routine inspections.

U.S. Naval Academy midshipmen operate an emergency tiller as a training exercise on the 60' (18.3m) Hood-designed sloop American Promise. *With good maintenance, the vessel's robust hydraulic steering system proved reliable for 20 years and thousands of miles of hard offshore sailing.*

For those total hydraulic system failures, workable manual-steering-system plans should be in place. In the more than three decades I've worked

When inspecting systems, look for accumulations of residue from fretting where moving surfaces work against one another. This installation correctly includes a washer between the bolt and the ball joint so that even if the latter fails, the ram remains connected to the tiller arm.

in the marine industry, I have seen many nicely made manual tillers that don't actually fit their matching rudderstocks, or were unusable in the cockpit as designed. And because even the most thoroughly planned, engineered, and installed systems may suffer from an unforeseeable material defect, it is imperative that manual tillers be tested for fit and function. They should not take more than a few minutes to rig and must work for a passage across the bay or, if necessary, hundreds of heavy-weather sea miles. PBB

***About the Author:** A former full-service yard manager, Steve now works with boat builders 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 Hull and Piping and Engine and Powertrain Project Technical Committees. He's also the technical editor of* Professional BoatBuilder.

PBB Information & Resources

Relevant ABYC Chapters
- P-21 Manual Hydraulic Steering Systems
- P-27 Electric/Electronic Steering Control Systems

Edson (www.edsonmarine.com)

Hynautic/SeaStar (www.seastarsolutions.com/products/hydraulic-new/inboard-new/hynautic-new/)

Jastram (www.jastram.com)

Jefa (www.jefa.com)

Kobelt and Accu-Steer (kobelt.com)

Raymarine (www.raymarine.com)

SeaStar Solutions – Teleflex (www.seastarsolutions.com)

Uflex (uflexusa.ultraflexgroup.com)

Wagner (www.wagnerengineering.ca/)

Whitlock/Lewmar (www.lewmar.com)