

STEERING

PART 1: Mechanical Systems

Installation and maintenance of cable, jacketed-cable, and geared steering systems begin our two-part series.

Text and photographs by Steve D'Antonio



After sail or engine propulsion, steering is one of the most important systems on any boat. In the systems inspections I conduct, I mark a deficiency as a *critical* or *important safety item* if the answer is “yes” to any of the following questions: Will a failure of this component cause the vessel to flood? Will it cause a fire? Will it injure a crew member? *Will it cause or lead to a loss of steering or control?*

Multiple steering systems have evolved over the past few centuries, the most basic of which, the rudder and tiller, is still used today. I remember as a boy sitting in the aft-facing seat of our family’s 16’ (4.9m) runabout marveling at the fully exposed “clothesline” cable-and-pulley steering system. The cable would periodically jump off the drum, requiring my father or brother (and then me when I was older) to slacken the whole system, rereeve it, and then tension everything up again. Such episodes taught me the value of a reliable steering system, especially when a failure occurred during vigorous maneuvering, typically when docking.

A variation on this cable-over-sheave system, sometimes referred to as chain-and-wire, is still used aboard the vast

majority of cruising sailboats less than 60’ (18.3 m) and some power vessels.

Cable over Sheave

The fundamentals of the system are straightforward enough. Beginning at the helm, a chain sprocket more robust than the one on a bicycle is attached to the wheel’s shaft. Over this sprocket a chain, preferably stainless steel, is laid, and to each end of the chain (which may be 2’– 4’/0.6m –1.2m long or more, depending upon how many turns the wheel makes from hard over to hard over) a stainless-steel-wire cable is attached. The cables travel, with the aid of sheaves to guide and turn them, to engage a quadrant attached to the rudder shaft. Thus, when the wheel is turned, the sprocket acts on the chain, which pulls on one side of the cable, which in turn places tension on the quadrant, causing the rudder to turn.

While this may sound complicated, it’s quite simple. In fact, the rugged simplicity of the cable-over-sheave steering system is one of its greatest attributes. *When properly designed, installed, and maintained*, these systems rarely fail.

Above—The best defense against mechanical steering system failures is regular inspections. On this pedestal-mounted cable-steering installation, at least the chain and helm sprocket are quite accessible.



Above left—This standard cable-over-sheave quadrant is partially installed. In service, the quadrant must be protected from any stored items, while being easy to reach for inspection and repair. **Above right**—The chain-and-sprocket assembly of this cable system runs close to multiple electrical components, which must be secured or physically isolated to prevent chafe. **Right**—This cable-over-sheave chain succumbed to crevice corrosion that grew from microcracking caused by the stresses of neglect or overtensioning. Thoroughly grease chains and sprockets, and every few years wash them in solvent such as kerosene before renewing the grease.



And when they do, they lend themselves very well to emergency repairs. Most failures involve parted cables or broken chains. The prudent skipper of a vessel equipped with such a system will keep a properly sized chain-and-cable assembly in his or her spares locker. At the least, a length of wire cable and several bulldog clamps should be kept on hand to jury-splice a parted cable.

Above all else, cable-over-sheave systems must be properly specified and sized for the application. If the system is not right for the vessel in which it's installed, its reliability and performance will be far from certain. Builders and refit yards should collaborate closely with steering system manufacturers to ensure a proper match.

The system must also be correctly installed. Of all the deficiencies I've found in cable-over-sheave steering-system installations, misalignment is among the most common. If the cable is not properly aligned with the various sheaves and the quadrant over which it turns, then the performance of the system, as well as the longevity of the cable itself, will suffer.



Precise cable-routing through multiple turning blocks is critical. If cables don't lie in the center of the sheave's groove, both will wear prematurely.



Left—Broken wire strands, or “meat hooks,” are a clear sign that a cable should be replaced. Even one broken strand is too many. **Right**—Another reason to be particular about leads is that where they unintentionally contact hose, electrical wiring, or wood, steering cables effectively become cutting tools.

An imaginary line drawn between any two sheaves, as well as lines drawn between the sheaves and the quadrant, must be perpendicular to the axle of the sheaves and rudder shaft. If the cable is not centered in the sheave and the quadrant grooves, it will drag on these components. Builders should pay careful attention to sheave placement and installation (articulating sheaves make this chore considerably easier), which sometimes requires shims or custom brackets. If, for instance, metal dust or tiny shavings are found beneath a sheave, it’s often a sign of poor alignment: each time the wheel is moved, the stainless-steel cable saws away at the bronze,

composite, or aluminum sheave. If allowed to persist, it will lead to a failure of one or more components.

It’s also important to note that bronze components, such as sheaves and quadrants, should not be used aboard aluminum-alloy vessels. Because of galvanic incompatibility, the smallest particles of bronze dust will often lead to corrosion when they come into contact with aluminum plating or other structures. Aluminum vessels should utilize only aluminum, composite, or stainless-steel cable-over-sheave steering components.

Cable terminations and quadrants also frequently suffer from improper installation. Cables in this system are

commonly terminated in one of two ways: using either a wire rope clamp, sometimes referred to as a bulldog clamp, or a permanently installed compression sleeve fitting, often referred to by the name of a popular manufacturer of these products, Nicopress.

Bulldog clamps (use only stainless-steel alloy clamps, preferably 316 in wet locations, and forged is preferable to cast) are reusable but frequently installed incorrectly. The cable “turn-back”—the distance the cable is paralleled against itself and where the clamps are installed—is a function of the cable’s diameter. For instance, $\frac{3}{16}$ ” (4.76mm) cable calls for a 3.75”

Left—Wire rope, or “bulldog,” clamps must be installed in only one orientation, with the “live,” or tensioned, portion of the cable retained in the clamp saddle, as illustrated here. **Right**—A cable should never be joined to a chain or quadrant without the benefit of a thimble to hold an appropriate radius in the wire and bear any chafe between the working components. Note that wire clamps should be stainless steel. The galvanized mild-steel ones, shown here, are beginning to rust.



(95.25mm) turnback, while $\frac{1}{4}$ " (6.35mm) cable calls for a 4.25" (107.95mm) turnback. The saddle, or open, end of the clamp should bear on the loaded or "live" portion of the cable (the mnemonic is "never saddle a dead horse," the dead end of the cable being the portion not under load). A minimum of two clamps, as well as a chafe-reducing thimble, must be used on every cable termination. Install the first clamp within a minimum of one-clamp-base width (approximately $1\frac{1}{2}$ inches) from the bitter end of the cable. The second should be installed as close to the thimble as possible without impinging upon it, with no slack between the two.

Torque requirements are a function of the clamp's size. For instance, $\frac{3}{16}$ " clamps call for 7.5 ft-lbs (10.2 Nm); while $\frac{1}{4}$ " clamps require 15 ft-lbs (20.3 Nm). Additional torque and installation instructions are available on clamp manufacturer websites. The clamp's nuts should be alternately tightened to reach the required tension. Heat-shrink tubing applied to the bitter end of the cable will prevent fraying and nasty jabs when working in this area.

Compression fittings utilize an alloy sleeve swaged over the cable turnback. The durable, strong sleeve requires the use of a special swaging tool, and once crimped, the sleeves are not reusable. Only stainless-steel or copper sleeves (the latter may be tin-plated, which appears silver and is often mistaken for stainless steel), *not* aluminum, should be used for stainless-steel-wire rope.

Normally, steering system terminations, whether they use compression fittings or clamps, are made in only two locations: to the chain at the helm using a stainless-steel self-locking shackle or chain adapter, and at the quadrant's take-up eye. Take-up eyes



Left—This well-executed chain-to-cable transition uses a Nicopress clamp to fix the cable eye. **Below left**—Take-up eyes are a cable-over-sheave system's fine-tension adjustment. The eye position should be locked with double nuts, as shown here, as well as by a single nut (not visible) on the other side of the quadrant-attachment point to prevent any eye movement. The lower structure attached to this rudderstock is a tiller arm, to which an autopilot ram will be attached.



one on the other side—that are designed to be locked against each other. Nut installation and location are critical to lock the adjustment and to prevent movement of the eye's shank.

The **quadrant** is the sole means of connection with, and application of torque to, the rudderstock. The stock is the metal post that forms the backbone of the rudder's internal support structure, beginning within the rudder blade and ending inside the boat. If the quadrant is not properly interfaced with the rudderstock, it will eventually fail. Typically manufactured in two pieces from manganese bronze or aluminum, quadrants must be machined to provide just the right amount of clamping action when installed. (The bore, or hole, in the quadrant is usually about 0.005"–0.006"/0.127mm–0.152mm smaller than the outside diameter of the rudderstock.) If the clamping action is insufficient, the quadrant could shift, leading to galling, and/or slide down the stock, causing cable misalignment and steering failure. If the clamping action is too great, the quadrant could bend,

are stainless-steel threaded rod (forged rather than cast) whose end is formed into a closed loop, or eye. They enable tension to be transferred from the wire rope to the quadrant, as well as affording *some* adjustment to the wire's tension. They are typically secured to the quadrant with three nuts—two on one side of the quadrant pass-through and

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Left—The bore in this radial drive casting was likely undersized for the stock, so it cracked when the clamping fasteners were tensioned. **Right**—If the design can support them, radial drives offer the potential benefit of eliminating a set of sheaves.

and crack when the affixing bolts are tightened.

In addition to the clamping action, the quadrant and stock must be securely locked together. On solid-

stock rudders the most common and preferred method uses a key that interfaces with keyways cut into the stock and quadrant. When properly fit and installed, this method is reliably

secure. Other methods include installing dual set-screws tapped into the quadrant cap as well as the rudder-stock or using a stainless-steel through-pin (not an ordinary bolt)

that passes completely through the quadrant and the stock. The latter two methods are often used on hollow-stock rudders.

For absolute security with either method, if all fasteners aren't nylon self-locking, use a thread-locking compound. As previously mentioned, metallic components must also be galvanically compatible: never use bronze quadrants on aluminum rudderstocks or vessels, or brass keys in aluminum rudder or quadrant keyways.

Radial drives, a variation on quadrants, utilize a 360° wheel, as opposed to the quadrant's partial arc. Often used on performance-oriented boats, radial drives are typically manufactured from anodized aluminum. Much like quadrants, they are built in two pieces and then clamped to the stock by the same methods of engagement: keys, pins, or through-bolts. The advantage to using a radial drive is

that, where geometry permits, two of the idler sheaves may be eliminated from the installation, simplifying the system and reducing weight while minimizing friction and wheel effort. Radial drives are well suited to vessels where cables can be led directly from the wheel pedestal to the rudder and where rudderstocks are vertical rather than raked fore or aft.

Tiller Arms

Although these are most often associated with hydraulic steering (which I'll discuss in "Steering, Part 2," in *Professional BoatBuilder* No. 175), tiller arms are used in conjunction with nearly every type of system to facilitate a connection between the rudderstock and a linear autopilot ram. Whatever the reason for using a tiller arm, it's important that sizing, fit, and attachment receive the same attention as quadrants and radial

drives. Naval architects, boatbuilders, and service yards must do their respective homework when sizing a tiller arm, be it for primary hydraulic steering or autopilot use (autopilots



Ideally, tiller arms should fit snugly against the rudderstock. The gap between the two halves of this clamp arrangement places extra tension on its fasteners.

The tight fit between the halves of the cast tiller and the rudder-stock minimizes torquing loads and makes a strong, reliable installation.



are often installed as an aftermarket item, so boatyards and electronics installers must get this portion of the equation right) to ensure proper operation. If the arm is too short, the ram may be overworked or not powerful enough to move the rudder. If the tiller arm is too long, insufficient travel may prevent the rudder from being put hard over (though it varies with vessel type, rudders typically swing through

an arc approximately 35° from amidships in each direction), and the rudder may impart too much force on the steering system or autopilot. Many manufacturers provide tiller arms with the choice of several connection points to the ram, offering some versatility.

Additionally, the geometry between the tiller arm and the ram must be correct to derive the greatest mechanical advantage when it's needed most—when the rudder is moved away from amidships; while it's dead ahead, the least effort is required. Ideally, and contrary to popular belief, the ram should *not* be positioned at 90° to the tiller arm and vessel centerline (assuming, in this example, that the tiller is fore-and-aft when the rudder is fore-and-aft) when the rudder is straight ahead; rather, it should be at 90° when the rudder is over to some degree (steering and autopilot manufacturers typically specify the degree) in either direction, thereby enabling the ram to impart greater force when it's needed most. This often means the ram, if installed athwartships, must be positioned farther aft.

The loads placed on tiller arms are considerable, no less than on quadrants



Counterintuitively, the angle between a steering ram and a tiller arm, when the rudder is dead ahead, should not be 90°. Shown here is a proper ram-to-tiller arm angle.

and often greater, because they are used for hydraulically assisted or fully powered steering and autopilots. Off-the-shelf tiller arms, as well as selection guidelines and assistance, are available from steering component

manufacturers. Much like the quadrant, the clamp fit must be just right,



For more on rudders, go to ProBoat.com.

not too tight and not too loose, and my preference is for a keyed interface whenever and wherever possible. Ram installation details are discussed further on the next page, in the Autopilot Installation Guidelines **sidebar**.

Cable over Sheave with a Twist

Among cable-over-sheave systems' many attributes is their rugged, reliable construction. To those at the helm, they also offer feedback, or feel for the rudder load. Aboard a sailing vessel



this is important because it often alerts the crew to the need for sail changes or trim adjustment. While hydraulic systems have their own advantages—especially their ability to send helm commands from the wheel to the rudder through long, often circuitous lengths of twisting, turning hydraulic hose without suffering any degradation in steering effectiveness—they offer no feedback. Because the helmsperson cannot determine how much load is being placed on the rudder, serious sailors often shun hydraulic

A pull-pull system relies on a jacketed cable similar in concept to that used for outboard steering and shift-and-throttle control. It allows for routing in ways a conventional cable-over-sheave system could not support. However, the jacketed cable is intolerant of high loads and sharp bends; a proprietary sheave system can accommodate the latter.

steering, and pull-pull steering systems come into play. These utilize cables and sheaves married to a flexible conduit that roughly resembles an outboard jacketed-cable steering system. The steering cable slides within this plastic-coated metallic jacket, or conduit, aided by ample grease.

The greatest advantage of a pull-pull system is that the run between the steering wheel or pedestal and the rudder need not be a series of straight lines, as is the case with traditional cable-over-sheave systems. The cable-and-jacket combination can make turns and bends, albeit gentle ones. Thus, center-cockpit sailboats, for instance, with notoriously difficult cable runs, don't have to resort to hydraulic steering, and feedback is maintained.

Pull-pull steering's limitations include, as one of the primary manufacturers of these systems warns, not making any 90° bends in the cable on

Autopilot Installation Guidelines

Although it was more than two decades ago, I remember the passage well. On a shorthanded delivery from Bermuda to New England, I was helping the skipper back to his home port and looking forward to a leisurely passage. Within a day of leaving St. David's Light in our wake, the boat inexplicably rounded up. After disengaging the autopilot, my shipmate took the wheel while I investigated with a flashlight. The autopilot drive motor—a chain-and-sprocket affair located in the binnacle under the wheel—had wrenched free from its plywood base, breaking one of its nylon gears. Along with squalls and heavy lightning storms, the voyage was plagued by other gear failures, and the autopilot drive could not be repaired with the vessel's onboard spares.

Autopilots are inextricably linked with a vessel's steering system, and proper installation is as critical as

selection, sometimes more so. An expensive full-function system poorly installed is worthless compared to an economy system correctly installed. Many builders tap the power of redundancy by installing twin autopilots on many oceangoing vessels, power and sail.

First, lay out the system mentally before committing it to paper. Visualize where each component will fit, where cables will be run, and what storage space will be lost. Take into account serviceability and access for repairs. How difficult will it be to reach each component, especially the drive mechanism? Will the drive or tiller arm (the device that connects the drive ram to the rudder) interfere with gear stored in this space? If so, a partition *must* be installed. If the autopilot uses a separate rudder-angle transducer, then this must be protected as well (rotary rudder-angle transducers are

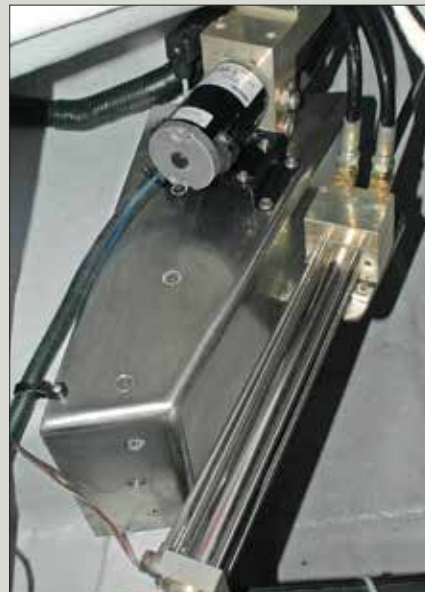


Proper autopilot installation on a quadrant or radial steering system should include an independent tiller arm like this one clamped to the rudderstock above the steering quadrant. Note the poorly routed, chafe-prone control cable running over the tiller arm—a common scenario in binnacle-equipped vessels.

more delicate than the linear variety). A single pull from a dockline, life jacket, or drawstring snagged on this

Right—Tiller arm length is determined by a pragmatic compromise between needed leverage and available throw.

Far right—Do not underestimate the loads imparted by autopilots to shelves and support structures. These designs must be robust and capable of withstanding thousands of cyclical loads.



important device could cause hundreds of dollars of damage, as well as an autopilot malfunction.

The linear drive unit is the autopilot component I've seen most often incorrectly installed. To understand the loads imparted to this area, do the following test: On a tiller-steered boat or even on a small outboard-powered dinghy, steer as you normally would, holding the tiller near its forward end. Now, choke up to within a few inches

of the rudder or outboard. It's almost impossible to control either one, especially in a beam or following sea. This is a crude but telling approximation of the loads a linear drive is subjected to with the average-length tiller arm for hundreds or thousands of hours. A chain-and-sprocket or geared system may face even greater torque. Accordingly, these drive units must be very solidly secured to the hull. Only through-bolts should be used to

secure the drive mechanism to a stringer, bulkhead, or well-glassed-in shelf, and backing plates are a must.



Pull-pull system internal steel cables ride inside a flexible steel jacket. Adequate lubrication to prevent drag and corrosion is essential. Grease cups, like the one shown here, aid in that effort.

vessels more than 30' (9.1m). Changes in cable elevation and direction should be kept as slight and gentle as possible; idlers (sheaves) should be used when a sharp(er) turn must be made. Critical in nearly all steering systems, lubrication is especially important in pull-pull systems. When in daily use, the entire system must be lubricated monthly. The manufacturer calls for

any conduit run of more than 6' (1.8 m) to be installed using a purpose-made greaser (a grease cup rotated to force grease into the conduit). The preferred lubricant for these systems must be low viscosity and typically Teflon-based, so grease cups can force it into the conduit.

In my experience, the primary modes of failure for pull-pull systems

are, as one might suspect, related to installation and maintenance as well as to overloading. Common shortcomings involve making too sharp or too many turns with the conduit and failing to use idlers at sharp turns or to properly terminate the cable end, which causes it to peel back, splay open banana peel-style, or be crushed like an empty soda can. Failure to lubricate the cable will, of course, accelerate wear and make steering labor-intensive.

The primary shortcoming of pull-pull systems, *when compared to traditional cable-over-sheave steering*, is they can't be easily inspected (the cable itself can be seen only at the ends), or repaired at sea without proprietary components. If this system should fail, repair parts must likely be obtained from the manufacturer. As with any steering system, vessel operators should carry a supply of relevant and correct

Do not use tapping screws or lag bolts. If you must do so, as shown in the right-hand **photograph** on page 32, they should be in as many different axes as possible—some in shear, i.e., perpendicular to the direction of effort. Use as many as

possible and as large as practical.

For hydraulic or electric linear rams, the dedicated autopilot tiller arm may be attached to the rudderstock at any location around the shaft, as long as it fully engages the key. Some quadrant manufacturers

prohibit piggybacking a linear autopilot drive onto the quadrant, and this makes good sense. Although it's more time-consuming and costly to install, an independent tiller arm affords greater redundancy. In the most popular types of mechanical steering for cruising sailboats—cable-over-sheave, pull-pull, or geared drag-link systems—if the cable breaks, or the quadrant slips, or some other component gives up, the boat can often still be steered with the autopilot if a separate tiller arm is used.

As mentioned in the main text, bronze and aluminum components are galvanically incompatible. Rudderstocks may be bronze, stainless steel, or in some cases aluminum (particularly on an aluminum vessel). Quadrants, as well as tiller arms, may be aluminum or bronze. Ensure that metals unfriendly to each other, particularly aluminum and bronze, are installed so they won't come in direct contact. Water dripping from a bronze tiller arm onto an aluminum quadrant or hull could cause severe galvanic corrosion over the years.

A final word on installation: It is critical that linear drive units have *more* travel than the tiller arm. They should never function as rudder stops, or shorten the travel of the rudder.

Aboard a sailing vessel with only one autopilot control/display, it is probably best to install it near the helm, so it can be adjusted, monitored, and disengaged easily. If installing multiple stations, or a handheld remote, the main unit should be at the navigation station, and the remote at the helm. Most remotes utilize a multipronged plug, but with the trend toward wireless accessories, other newer models are not limited by this electronic tether.

Because the drive unit's electrical consumption can be prodigious, especially in a seaway, a voltage drop



Outboard-powered vessels often utilize what's known as a push-pull system, which employs a jacketed, internally lubricated cable. The cable's primary weakness is seizure after long disuse, so it's difficult to lubricate it too much.

spare parts, as well as an emergency tiller.

Push-pull systems (a variation on the pull-pull technology) have been broadly applied to steer outboard and stern-drive vessels for more than half a century. Available in rotary or rack-and-pinion designs, a single rigid-core,

jacketed cable translates rotary motion from the wheel to linear motion at the engine or stern-drive. Helms should be matched to the load; larger, heavier engines and boats call for lower gears, resulting in more turns lock to lock, with lower effort. Systems are available in conventional planetary as well as

reduction-gear (the latter use smaller gearboxes) versions, as well as those that eliminate feedback, making for safer operation as the wheel does not rotate quickly should a driver lose his or her grip.

The most common failure modes for push-pull systems involve seized

of no more than 3% must be achieved. The calculation for this formula must include a “there and back” figure for the electrical-supply cable. If, for instance, the drive unit is 20’ (6.1m) from the main power-distribution panel, the voltage-drop formula would utilize 40’ (12.2m) of cable for the overall run. This information can be found in the ABYC Standards and elsewhere. In addition to performance and efficiency, a low-voltage scenario can noticeably shorten the life of an electric motor, and under-sized cabling will surely exacerbate this. Connect the drive unit and power supply via an insulated marine-rated terminal block to accommodate the difference in wire size between the drive unit and vessel side of the cable run as well as to ease service and replacement. Ideally, the autopilot

wiring’s overcurrent protection should be a circuit breaker rather than a fuse. If a failure occurs, it may take several blown fuses to identify the problem. Then they must be replaced, whereas a circuit breaker can simply be reset.

To help ensure the reliability of a **hydraulic autopilot**, i.e., a hydraulic pump that acts on the vessel’s existing hydraulic steering, rams, etc., follow these details: Size the pumps to meet the demands of the vessel’s displacement, rudder size, and speed. Plumb the pumps with isolation valves that limit damage in the event of a leak. All valves, plumbing, hose, etc. must be rated for the system’s relief pressure, which, even for manual systems, is typically 1,000 psi (69 bar). The above-mentioned wire size and circuit breaker issues apply here as well.

I routinely see valves and cast-bronze plumbing fittings rated for 400 psi or 600 psi (27.6 bar or 41.4 bar) in these systems, with many of the valves leaking from stem seals. Make certain that the autopilot’s motor and solenoids are rated for the vessel’s voltage. In some cases, mismatched pumps and components will work for some time before failing.

Electrical connections should include service and drip loops in each wiring run. Heat-shrink connectors offer the greatest degree of strain relief and water resistance. Overcurrent protection for the entire autopilot system should be a circuit breaker as opposed to a fuse. The circuit breaker should be easily accessible, well labeled for resetting, and dedicated to the autopilot alone.

Most installation manuals are fairly

Installing the helm radial gear-box of a push-pull system on a small runabout presents its own challenges in meeting cable manufacturers' bend-radii limits to ensure smooth operation.



cables (the ends are stainless steel, however the core and jacket cables are mild steel, so if the outer plastic jacket is pierced, water will enter, causing rust and seizure); cables seized inside outboard tilt tubes; and stripped helm gears. Most cables are

embossed with a part number and length. While a seized cable can sometimes be freed up, and a tilt tube cleaned with a bronze rotary brush and lubed, repairs are typically impractical. Cables and helms are simply replaced when no longer

functional. Lubrication with high-viscosity water-resistant grease and regular inspections for wear and loose fasteners are key maintenance items.

Push-pull systems are available in single- or dual-station designs. Those working on and repairing these systems must always demand original equipment manufacturer parts for new installations and repairs; field-substitutes are unacceptable.

Geared, and Rack-and-Pinion

The final mechanical system we'll discuss utilizes neither pulleys nor conduits but instead the tried-and-true interface of metal teeth, threads, and gears. In one form or another, geared steering systems have been around for well over a hundred years. Worm gears offered strong, reliable steering to many craft both power and sail; they are considerably less common now, available from only a



Left—Many vintage steering systems like this worm gear rely on mild steel parts, making inspection, lubrication, and corrosion inhibition critical.

Right—Similarly, reliable rack-and-pinion systems, which expose the lubricating grease to open air and contamination, should be periodically cleaned and the grease replaced.



few manufacturers. Their primary advantages are strength and simplicity, but the design limits feedback to the helmsman, so they are not recommended for balanced rudders and fin keel boats, where a sensitive helm is a virtue.

Another variety of geared steering system has become popular in recent

years. Referred to as rack-and-pinion, or drag-link, steering, this system offers the advantages of using neither cables, sheaves, nor conduits and has more in common with the system in an automobile than with those aboard boats. Rack-and-pinion systems (with a variation being gearbox steering, with a gear-to-gear interface rather

than gear-to-rack), offered by several manufacturers, are strong and rugged and provide feedback to the helmsperson. Used primarily on sailboats, a circular geared rack in the helm pedestal is turned by a pinion attached to the wheel shaft. As the rack rotates, it turns a vertical torque tube connected to a tiller arm at its base. This tiller arm



The majority of hydraulic autopilots and manual hydraulic steering systems operate with a relief pressure of 1,000 psi (69 bar). All plumbing components—rams, hoses, and fittings—in these systems must carry this minimum pressure rating.

specific about where and how to mount the fluxgate compass. Of course, the farther this component is



from large iron masses, such as the engine and anchor/rode, or electric motors, pumps, and high-current cabling, the better. Post placards in lockers and storage spaces adjacent to the fluxgate compass prohibiting the storage of ferrous metal objects (one can of beans can ruin an autopilot and your day). Install the fluxgate

Ideally, autopilot fluxgate compasses should be installed no closer than 1m (3.3') to ferrous metals, including tools, motors, and even some tinned foods.

temporarily until sea trials are complete to ensure that it's well placed and not affected by any of the aforementioned objects.

Swinging or calibrating the compass is a critical part of the installation. Follow the manufacturer's instructions meticulously. When calibrating, it is best to energize all loads that will normally be on while you are under way, day and night. Electric current sets up a magnetic field that will sometimes affect the performance and accuracy of any compass.

—Steve D'Antonio



More akin to the systems in automobiles, drag-link steering does not use cables, jackets, or hoses. Instead, gears, lever arms, and tie rods allow the system to convert rotary to linear motion and transmit movement to the rudder.

is attached, via an adjustable drag link or tie-rod, to a similar tiller arm located on the rudder shaft. Referred to as wide-angle geometry, there's a value-added benefit to this type of system: by making the tiller arm that's attached to the base of the torque tube shorter than the tiller arm attached to the rudderstock, the mechanical advantage

increases with the rudder angle, while maximum sensitivity is maintained when the rudder is amidships.

This means that as the rudder is turned farther, which increases the resistance placed on it, the angle between the drag link and the centerline increases, which in turn diminishes the effort required to turn the

wheel. It's critical that these systems be set up properly to ensure that the steering operates with the least effort. I've seen several production vessels whose drag-link-steering systems were installed incorrectly at the factory, making for erratic or overly strenuous steering. Installing any steering system per the manufacturer's


guidelines is well worth the effort. Because corrosion can be an issue on key components made from mild steel, they should be carefully inspected, particularly in existing systems, and may require supplemental corrosion inhibition.

To utilize this system, the vessel must be designed so the drag link can

be installed between the wheel and the rudder. If the wheel is too far from the rudder (with bulkheads or other interior structures between them) or if the elevation between the rudderstock and the base of the cockpit is significantly different, it may not be possible to use this type of steering. And, much like other systems that use proprietary

components, drag-link steering nearly always requires special parts for repairs.

The good news is that the simplicity of this robust system makes failures uncommon. Regular inspections and lubrication of all moving parts and bearings, as well as periodic maintenance, will help ensure trouble-free performance.

Hydraulic steering systems for power and sail will be discussed in “*Steering, Part 2*,” in the next issue, PBB No. 175. 

About the Author: *For many years a 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 Transmission Project Technical committees. He's the technical editor of Professional BoatBuilder.*

Information & Resources

Relevant ABYC Chapters

P-17 Mechanical Steering Systems

P-18 Cable over Pulley Steering 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)

Wagner (www.wagnerengineering.ca/)

Uflex

(uflexusa.ultraflexgroup.com)

