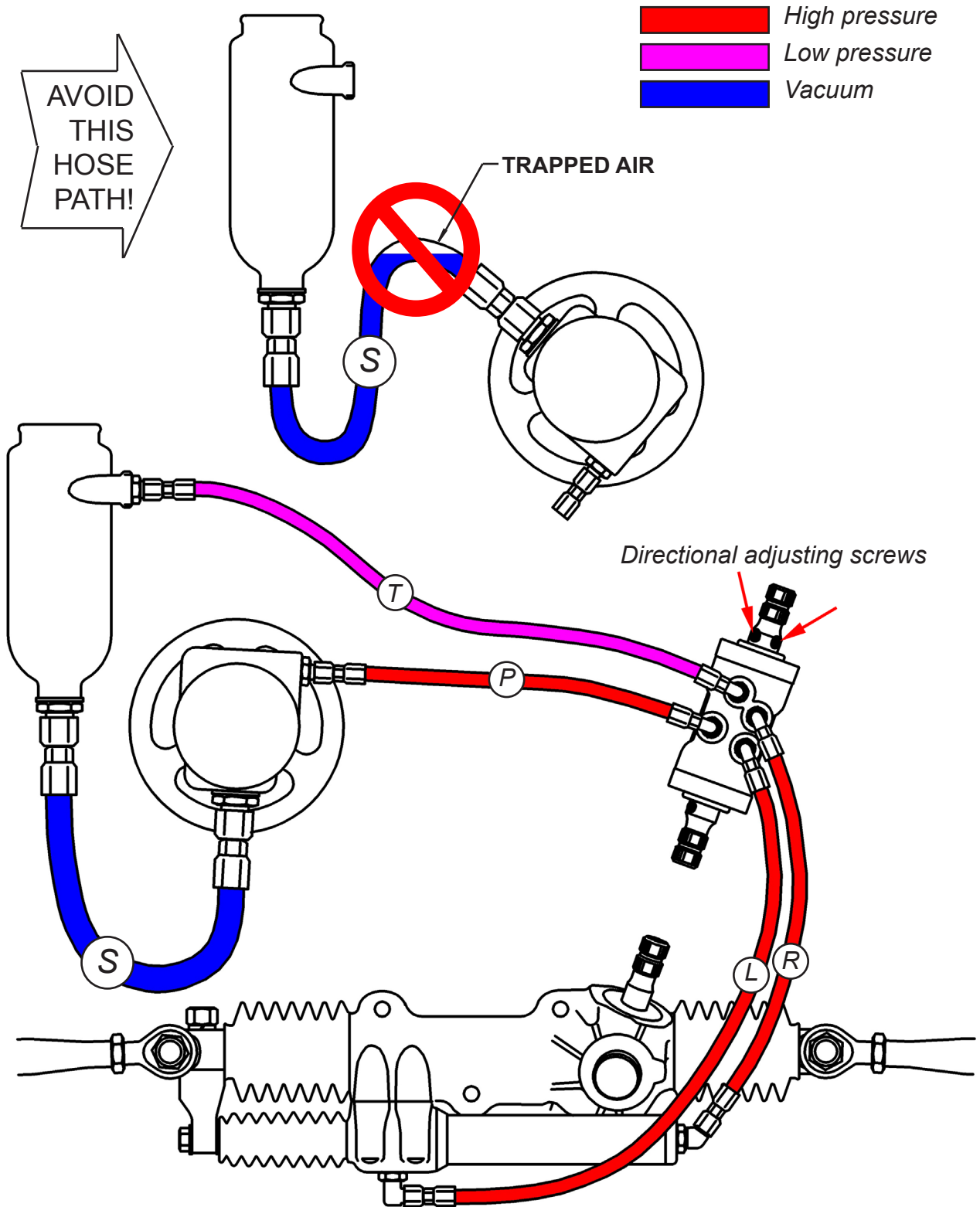


Hydraulic power steering fluid circuit

Although this drawing shows a layout typically used on oval track stock cars, the operating principle is the same for any hydraulically assisted steering, regardless of component placement. The following pages explain in detail the functions of the various hoses to help you analyze problems. Note that the “vapor lock” condition shown here is responsible for the vast majority of power steering issues on race cars:



(P) High pressure when TURNING in either direction

Fluid is pumped through the P line at a constant rate at relatively low pressure until a steering load is applied, at which time **the pressure rises throughout the working side of the system**. For example:

Turning the steering wheel to the RIGHT simultaneously pressurizes the output side of the pump, the P line, the P and R channels of the servovalve, the R line and the R side of the cylinder.

Turning it to the LEFT pressurizes the output side of the pump, the P line, the P and L channels of the servovalve, the L hose and the L side of the cylinder.

Note that the system is pressurized on demand through the P line, regardless of direction.

The working pressure in steering can approach 1600 PSI, so the L, R, and P hoses must be rated for it.

(L) High pressure when turning LEFT; exhaust when turning RIGHT**(R) High pressure when turning RIGHT; exhaust when turning LEFT**

The L and R lines alternate between pressure IN and exhaust OUT according to the direction in which turning effort is applied to the steering wheel.

With the steering effort relaxed, the pressure in both lines is low. They are both filled with fluid but the flow is static. Turning the steering wheel allows additional fluid to flow into the appropriate side of the cylinder and build pressure against one side of a two-way piston. The pressure will rise exactly as high as necessary to overcome the resistance of the front wheels. Viewed another way, the pressure will rise exactly as high as necessary to prevent the steering wheel from overcoming the driver's resistance. The system reacts to torque momentarily existing in the steering wheel; it does not matter from which end the torque originates.

As one side of the cylinder is pressurized through one line, the other side is exhausted through the other line. Torque in the other direction instantly reverses these functions.

In most systems the pressure in the lines with fluid circulating under no load, or exhausting, will be less than 125 PSI. The pressure in the lines while performing work is limited by the pump relief valve, which in current practice may be set as high as 1600 PSI.

(T) Low pressure return (exhaust) to tank

The T line constantly returns all circulating fluid to the tank, including fluid momentarily exhausted from either side of the cylinder through the L and R lines as the steering wheel is turned. Once it has entered the return side of the circuit the fluid is not available to perform work. It essentially becomes a dead load, so it is important that the return flow be unimpeded. If the hose is longer than 3 feet, or is routed through an obstruction such as a cooler, a larger -8 hose should be considered.

The best way to ensure maximum return flow is to vent the tank to atmosphere. If the tank is not vented, the normal heat of operation will cause back pressure to build up. The effectiveness of power steering depends on being able to instantaneously create as great a pressure differential as possible between the working and exhaust sides of the circuit. Back pressure reduces the efficiency of the steering system in much the same way as a restricted exhaust pipe taxes an engine.

(S) SUCTION from tank

The S line supplies the pump intake. This hose is larger than the others (-10 or -12 size) because the suction side of the pump is aided only by gravity. In order to remain primed, the pump must be located below the level of fluid in the tank. The S hose must be of a reinforced type that will resist contraction from suction, which in a power steering pump can momentarily reach 26 inches of mercury—a very powerful vacuum. Collapse of the S line will starve the pump and shut off the power assist.

Important: Braided-stainless-covered NEOPRENE rubber hose (the kind usually supplied with red and blue ends) does not meet this requirement. It has no structural resistance to collapse, and after a few laps' worth of softening by hot oil, a high-volume pump can easily suck it partially or completely shut. The same is true of push-lock hose.

Acceptable hose types for this service include any hydraulic hose carrying a vacuum rating as above—provided the hose does not have a thick wall and reduced bore. Braided-stainless-covered PTFE core is much stiffer than the neoprene type and will work very well but care must be taken to prevent kinks.

How to bleed power steering

Remove the tank lid. With the engine off and the car's front wheels off the ground, SLOWLY move the front wheels back and forth through their full travel while listening for air bubbles squirting into the tank. Each time the steering moves through its travel one way, the piston will displace fluid from one side of the cylinder, push it into the servovalve, and from there into the return line. Note that upon reversing direction any bubbles which did not reach the return line will be sucked back into the cylinder, so extra-long L and R hoses will require more strokes to purge all the air. Be patient; if the pump has been running there may be air dispersed throughout and it may need a few minutes to settle. Thicker fluids will hold bubbles in suspension longer. Since the T line leads upward to the tank it will self-bleed; the goal is to get the air out of the cylinder and through the servo.

Avoid air traps or "vapor lock"

In general the S line should be as short and direct as possible, but above all it must not trap air. A hose which approaches the pump from below and enters it from above—as in the illustration—will have an air pocket at the top of the bend, which de-primed the pump. The effects range in severity from "surging" or intermittent steering at certain points on the race track to extremely hard, jerky steering which can barely be turned with the car stationary. The slightest high point in a level-appearing run of hose can trap air. Slower-turning pumps such as those coupled to a dry-sump pump tend to lose suction at lower engine speeds and are especially vulnerable to this problem.

Note that pressurizing the reservoir with air can inflate the supply hose against collapse, but (contrary to a popular belief) it cannot supercharge the pump intake nor remove an air trap. Power steering is a closed-loop system. A reservoir pressurized to "feed" the pump resists returning fluid with identical force—otherwise known as back pressure. The highest efficiency, along with lowest back pressure and waste heat, is obtained with a vented tank mounted higher than the pump so as to maintain a positive prime, with a reinforced suction hose routed to eliminate air traps.

Prevent turbulence

Unless you have a de-aerating tank, the fluid level must be maintained above the return port to prevent returning fluid from disturbing the surface enough to draw air into the oil. Air is a compressible medium and its presence in the fluid will cause the steering to chatter or be generally weak. If the return port is too low in the tank, any returning air will be drawn directly into the suction line before it can be vented.

How to field-test a pump

Fluid normally flows from the tank, to the pump, to the servo, and back to the tank, at a practically constant rate under all conditions, until the cylinder reaches the end of its travel and puts the pump into relief, at which point flow through the system should immediately cease. In relief mode, also known as "bypass," fluid merely circulates within the pump without performing work. The pump can also be put into relief by a steering load which demands a working pressure higher than the pump's preset relief point will allow, OR from a flow-control circuit which is stuck open from dirt; see next page. To test a pump, disconnect the return line and hold it over the tank. If the flow stops when you try to turn the wheels, the pump is stuck in relief.

How to adjust the directional balance

The Woodward servo has a pair of set screws located in the input shaft, spaced at 90 degrees. With the car up on stands, start the engine and open the throttle enough that the pump turns at least 1000 RPM. If the steering drifts one way by itself, shut the engine off, loosen the screw on the opposite side, which will let you tighten the one on the side it drifts toward. For example, if it drifts to the left, loosen the right screw and tighten the left. Restart the engine and observe the change. The adjustment is quite sensitive; about 1/12 turn—the distance between numbers on a clock face—is normally enough to make a difference. It may take a couple of tries, but when it no longer drifts you have balanced the power steering. Set the car on the ground. At this point the only pull will be from your caster split. You can adjust that out with the screws. You can even make it countersteer by itself, which can make driving easier on a heavy track. Make sure both screws are tight enough not to shake loose. If that happens the steering will wander. Caution: Never put a wrench in the adjusting screws with the engine running.

Loss of power assist due to a stuck flow control piston

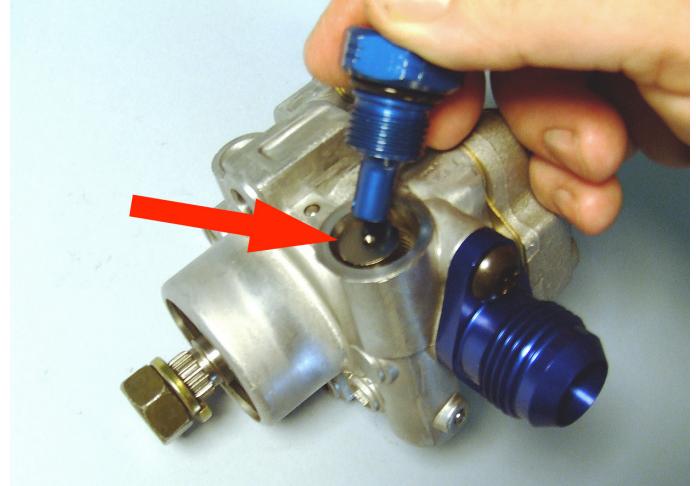
Power steering pumps, unlike ordinary hydraulic pumps, are internally regulated to keep the output flow constant regardless of RPM. Without this important feature, the power assist would be weak at low speeds and overpowering at high speeds, which in an automobile would be functionally backwards. The flow is controlled by means of a small piston which is held against the outlet fitting by a return spring, and forced back into its bore as back pressure is created at the outlet orifice. The piston travel uncovers a fluid port, venting oil back into the pump and keeping the output flow constant.

The piston moves constantly in reaction to engine RPM. The higher the RPM, the higher the back pressure at the orifice, and the farther the piston travels.

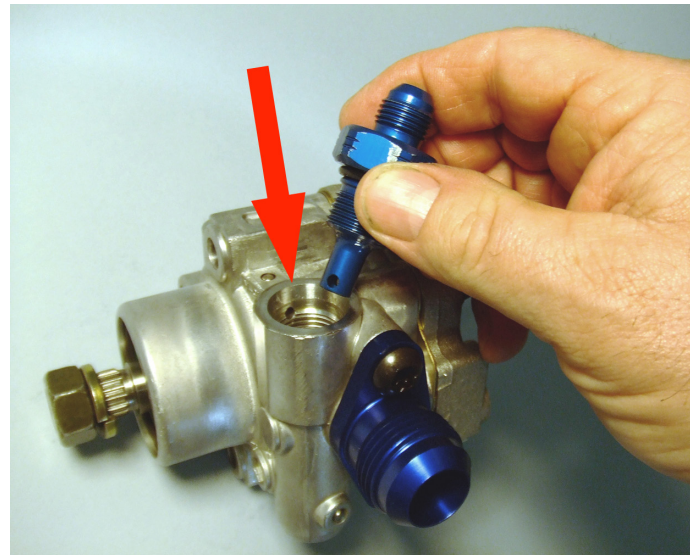
Any obstruction in the bore can prevent the piston from returning completely, and each following surge of RPM-induced pressure will wedge the piston progressively farther open, until the outlet is completely bypassed. In this condition the pump will still circulate oil but will not create enough pressure to operate the steering.

A stuck flow control is indicated when oil returning to the tank stops when steering effort is applied.

A bare aluminum bore is vulnerable to the raising of a burr from a small dirt particle or piece of metal debris. As the piston oscillates it will roll up the slightest burr just like a snowball until it is wedged tight. Rebuilding the pump should include careful removal of any sharp edges where the bore is intersected by drilled holes.



Normal: the piston will pop out as the fitting is removed.



If the piston stays stuck down in the bore, the pump cannot create any output pressure and the power steering will not work.

Loose or wandering steering due to a rocking rod bracket

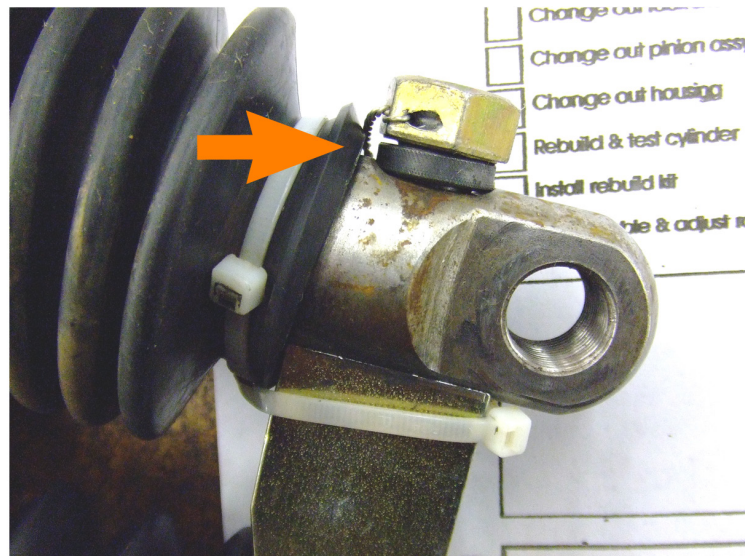
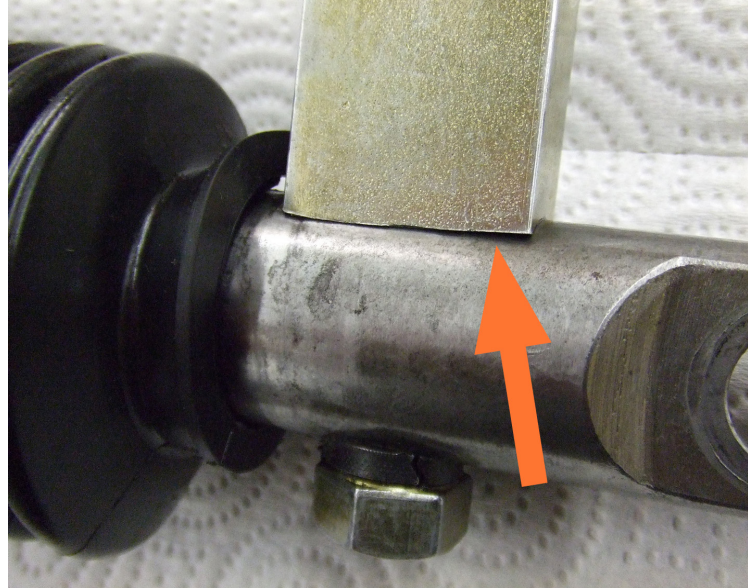
The rod bracket transfers the force of the piston rod to the rack, and on dirt tracks is subject to severe vibration as well as heavy reversing loads.

The bolt has a long engagement in the bracket and should be tightened to 90 lb/ft lubricated.

Check the rod bracket regularly. If you find you have to retighten the bolt, that is an indication that the bolt is stretching. A bracket which has been working loose will show a characteristic mushroomed mating surface which no longer fits tightly against the rackshaft (seen at right). With the bracket rocking back and forth, the connection between the rack and the power assist will be vague and sloppy.

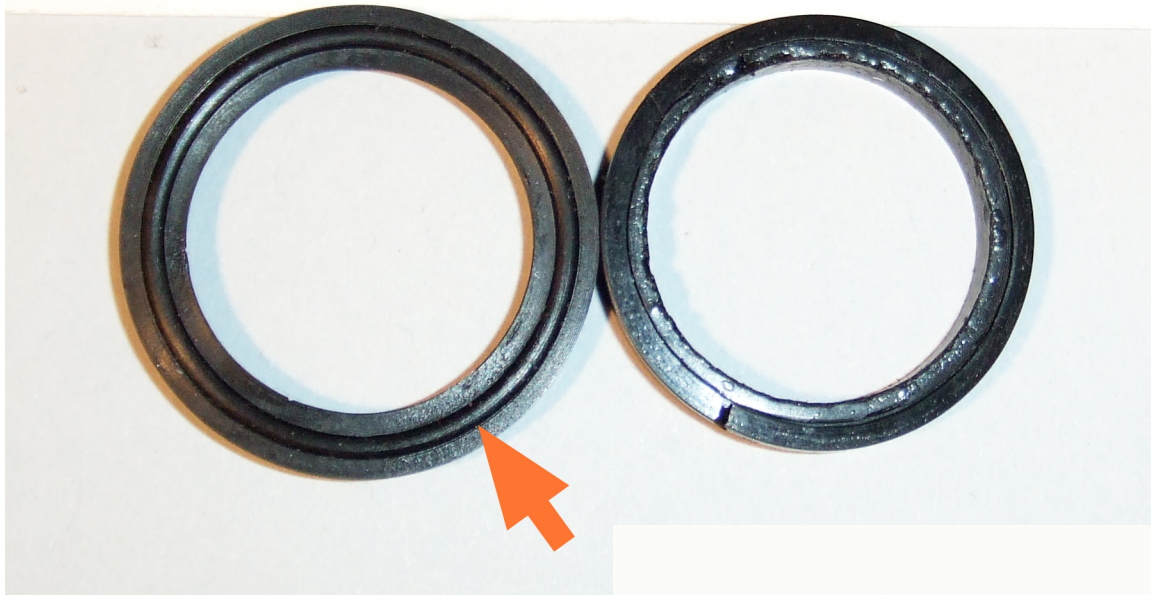
In this condition the bolt will flex under load until it breaks from metal fatigue. If discovered to have been running while loose, **BOTH BOLT AND BRACKET SHOULD BE REPLACED** as soon as possible. Replacing only the bolt is just a temporary fix.

Note that in order for the bracket to maintain a solid "footprint" against the rackshaft, the bolt must be under clamping tension. There is no substitute for checking tightness with a wrench. As can be seen at right, safety wire is a nice-looking touch and will prevent the bolt head from being lost on the race track, but cannot by itself preserve bolt tension.



Fluid leakage around input shaft while car is parked, due to effects of chemically aggressive synthetic power steering fluid or ATF

Below are two identical polyurethane loaded lip seals (part number R581, used at the ends of the servo), removed after about 60 days' service. The one on the left was exposed in operation only to mineral-oil (petroleum) based power steering fluid and the one on the right to various "synthetic" aftermarket fluids. In neither case did the operating temperature exceed 220° F., however, the one on the right exhibits embrittlement as well as considerable shrinkage, while the one on the left is still functional.



The energizing O-ring (orange arrow) is actually present in both seals, but the one at right has shrunk by about 20% along with the rest of the seal profile. Obviously the shaft acted as a mandrel and prevented the inner diameter from getting smaller, but the outer diameter shrank enough that it pulled completely out of contact with its groove (area indicated by blue arrow at right) allowing fluid to flow around the seal from gravity alone once the engine was shut off and the power steering system depressurized.

Interestingly, system pressure with the car running is often sufficient to inflate the seal in its groove and temporarily stop the leak.

