



Chapter 4

Power Steering (Mechanical)

- Introduction of power steering
- Power steering hydraulic system layout
- System components, construction and operation
- Steering troubleshooting, diagnosis, and service procedure

4.0 Introduction

Power steering systems have contributed to reduced driver fatigue and made driving a more pleasant experience. Nearly all power steering systems at the present time use fluid pressure to assist the driver in turning the front wheels. Since driver effort required to turn the front wheels is reduced, driver fatigue is decreased. The advantages of power steering have been made available on many vehicles, and safety has been maintained in these systems.

There are several different types of power steering systems, including integral, rack and pinion, hydroboost, and linkage type. In any of these systems, the power steering pump is the heart of the system because it supplies the necessary pressure to assist steering.

The power steering pump drive belt is a simple, but very important, component in the power steering system. A power steering pump in perfect condition will not produce the required pressure for steering assist if the drive belt is slipping. Various types of steering systems, drive belts, and pump designs are described in this lecture.

4.1 Power steering pump drive belts

Many power steering pumps are driven by a V-belt that surrounds the crankshaft pulley and the power steering pump pulley. The V-belt may also drive other components, such as the water pump. The sides of a V-belt are the friction surfaces that drive the

power steering pump Figure 4.1. If the sides of the belt are worn and the lower edge of the belt is contacting the bottom of the pulley, the belt will slip. The power steering pump pulley, crankshaft pulley, and any other pulleys driven by the V-belt must be properly aligned. If these pulleys are misaligned, excessive belt wear occurs.

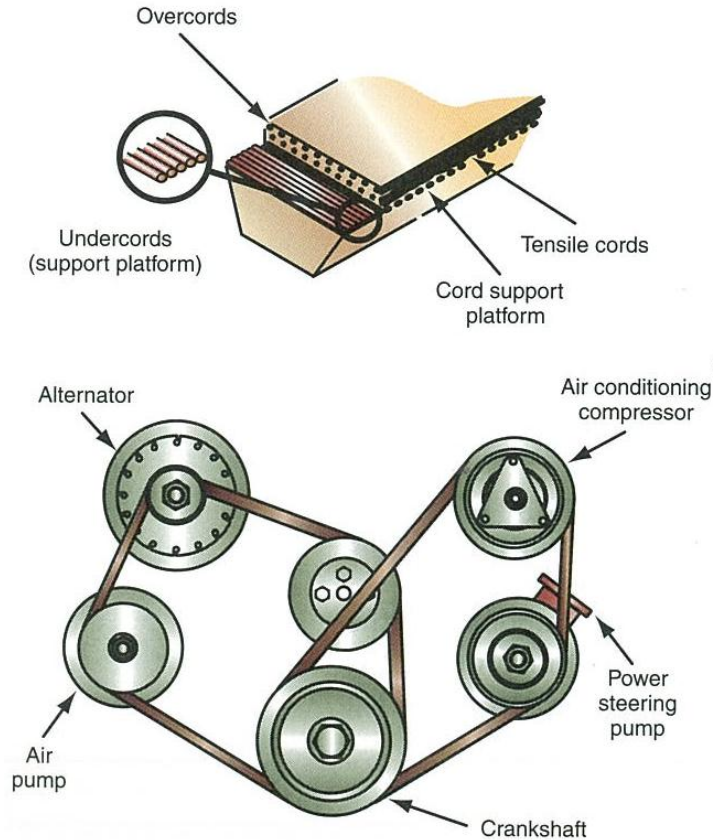


Figure 4.1: Conventional V-belt

A serpentine belt is used on many vehicles, and this belt may be used to drive all the belt-driven components. The serpentine belt is much wider than a conventional V-belt, and the underside of the belt has a number of small ribbed grooves. Most serpentine belts have spring-loaded automatic belt tensioners that eliminate periodic belt tension adjustments. Since the serpentine belt may be used to drive all the belt-driven components, these components are placed on same vertical plane, which saves a considerable amount of underhood space Figure 4.2. The smooth backside of the serpentine belt may also be used to drive one of the components. Regardless of the type of belt, the belt tension is critical. A power steering pump will never full pressure if the belt is slipping.

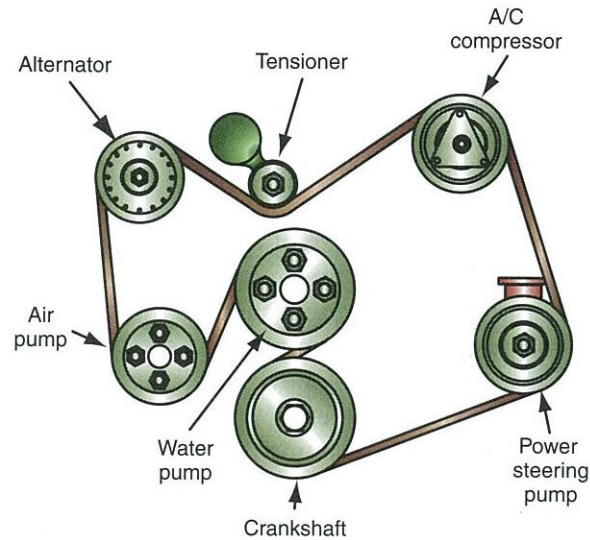


Figure 4.2: Serpentine belt

Some current vehicles are equipped with a stretchy belt that does not require a belt tensioner or belt adjustment. The stretchy belt has a similar appearance compared to a conventional serpentine belt. However, stretchy belts have tensile cords made from a polyamide material that is three times more elastic compared with the cords in a conventional serpentine belt. In a stretchy belt, the rubber layers around the cord layer have superior durability and improved adhesion to the cord layer to accommodate the stretching action. Eliminating the mechanical belt tensioner saves weight, space, and financial cost. The stretchy belt is usually installed only around two pulleys such as the A/C compressor and crankshaft pulleys, and the remaining belt-driven components have a conventional V-belt drive.

If a stretchy belt requires replacement, the vehicle manufacturer recommends cutting the old belt to remove it. A special tool is used to lift and guide the new stretchy belt onto the pulley.

4.2 Types of power assisted steering systems

4.2.1 Rack and pinion steering system

The rack and pinion power steering system is used on most front-wheel-drive cars. In this steering system, the power steering pump is bolted to a bracket on the engine, and the pump is driven by a belt from the crankshaft. In most front-wheel-drive cars, the engine is mounted transversely, and the steering gear is mounted on the cowl behind the engine or on the cross-member below the engine Figure 4.3.

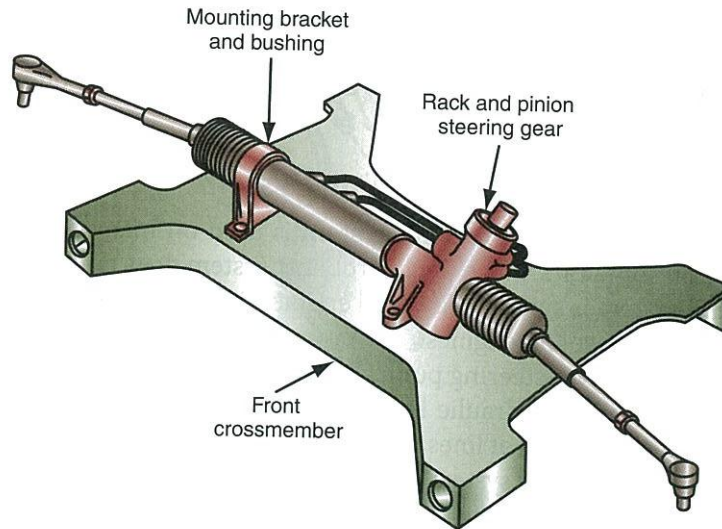


FIGURE 10-3 Power steering gear mounting.

Figure 4.3: Power steering gear mounting

In many power-assisted rack and pinion steering systems, an integral reservoir is part of the power steering pump. A dipstick is mounted in the reservoir for fluid level checking Figure 4.4. A high-pressure hose and low-pressure return hose are connected from the pump to the steering gear Figure 4.5. The high-pressure hose usually a steel-braided hose with appropriate fittings in each end. The return hose is a rubber-braided hose that is clamped to the fittings on the pump and gear.

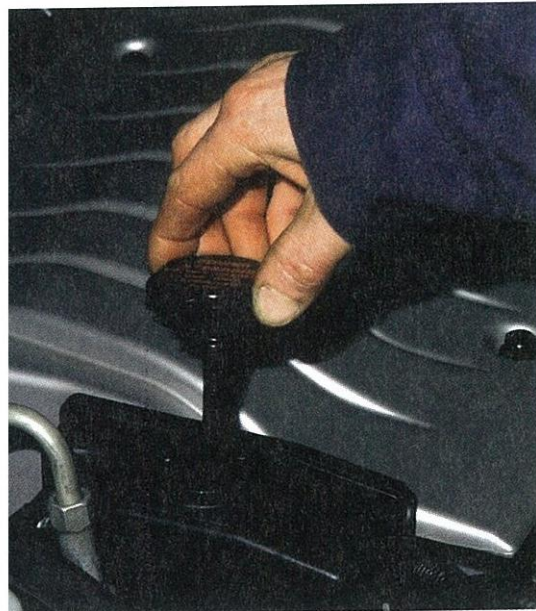


Figure 4.4: Power steering reservoir and dipstick

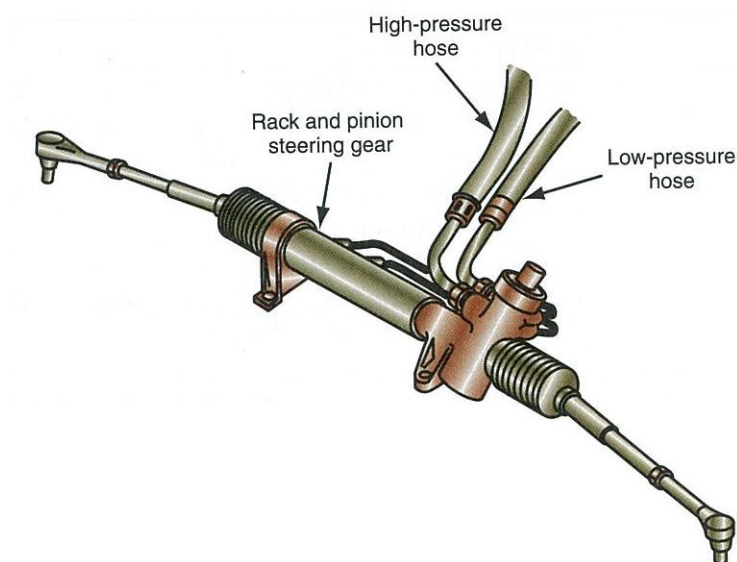


Figure 4.5: Power steering pump to gear hoses.

Some power-assisted rack and pinion steering systems have a remote reservoir. This type of system is commonly used on small cars with limited underhood space where it may be difficult to access an integral reservoir on the power steering pump. The remote reservoir is placed in a convenient position, and the return hose is connected from the steering gear to the reservoir. A second return hose is routed from the reservoir to the pump Figure 4.6.

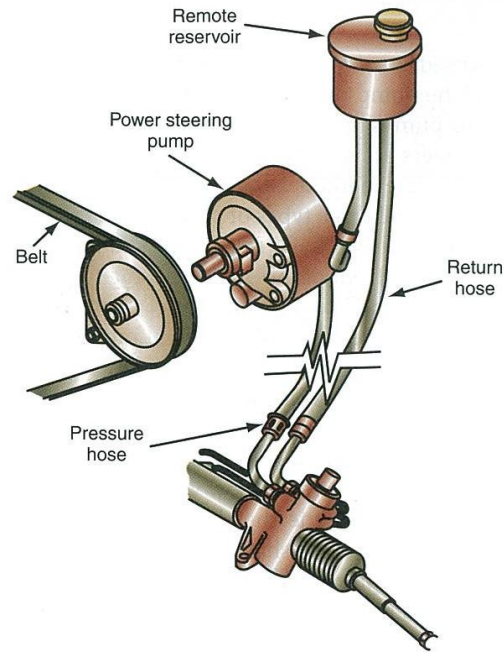


Figure 4.6: Remote reservoir on power-assisted rack and pinion steering system.

4.2.2 Integral power-assisted steering system

In the integral power-assisted steering system, the pump is bolted to a bracket on the engine, and the recirculating ball steering gear is mounted on the frame beside the engine. This type of steering system is used on many rear-wheel-drive cars and light-duty trucks. The pump is driven by a belt from the crankshaft and an integral reservoir is mounted on the pump. A high-pressure hose and a return hose are connected from the pump to the steering gear Figure 4.7.

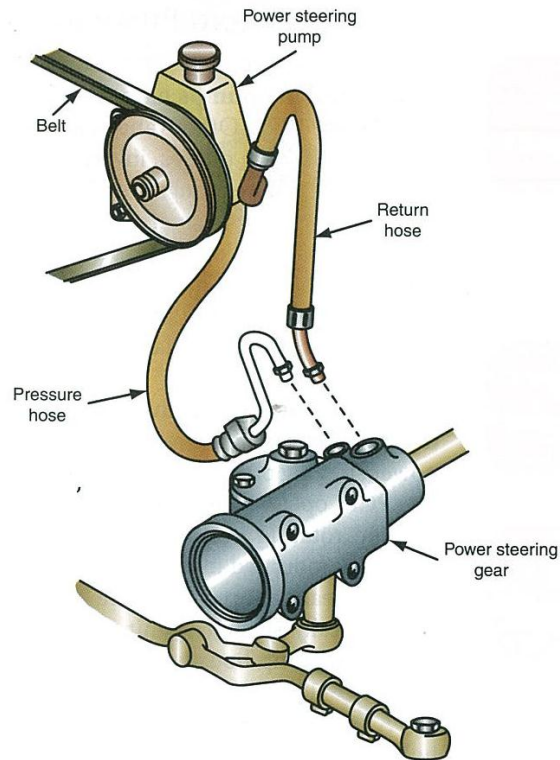


FIGURE 10-7 Integral power-assisted steering system.

Figure 4.7: Integral power-assisted steering system.

4.2.3 Hydroboost power-assisted steering system

The hydroboost power-assisted steering system is used on many light-duty trucks with diesel engines and on some cars. Since the hydroboost system does not use manifold vacuum for brake assist, this system is suitable for diesel engines, which have reduced intake manifold vacuum compared with gasoline engine. The power steering on these systems is similar to an integral unit, but the power steering pump pressure is also applied to the hydroboost unit in the brake master cylinder. Hydraulic lines are routed from the power steering pump to the steering gear, and another set of lines is connected from the pump to the master cylinder Figure 4.8. In the hydroboost system, the power steering pump pressure applied to the master cylinder pistons acts as a brake booster to assist the driver in applying the brakes. The hydroboost system does not have a conventional vacuum booster on the master cylinder.

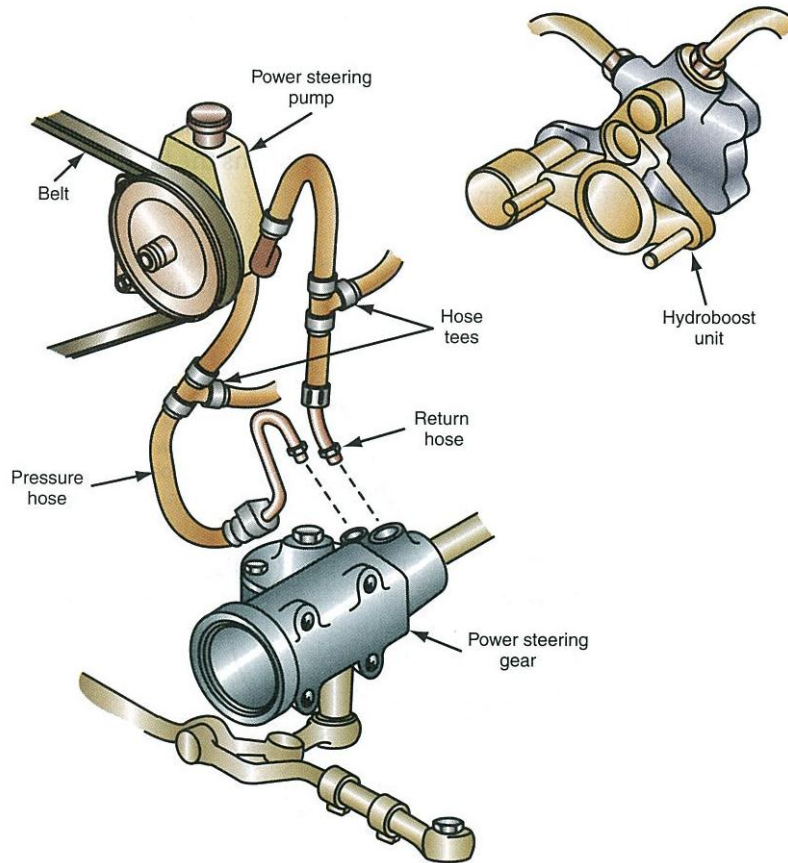


Figure 4.8: Hydroboost power-assisted steering and brake system.

4.3 Power steering pump design

Various types of power steering pumps have been used by car manufacturers. Many vane-type power steering pumps have flat vanes that seal the pump rotor to the elliptical pump cam ring Figure 4.9. Other vane-type power steering pumps have rollers to seal the rotor to the cam ring. In some pumps, inverted, U-shaped slippers are used for this purpose. The major differences in these pumps are in the rotor design and the method used to seal the pump rotor in the elliptical pump ring. The operating principles of all three types of pump are similar.

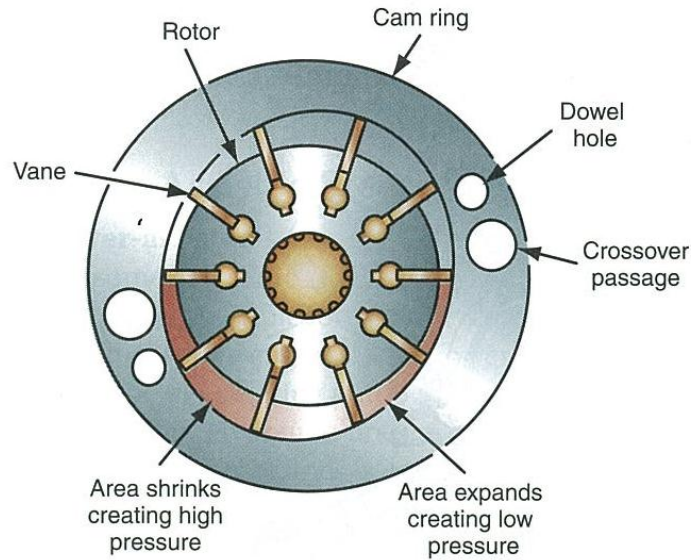


Figure 4.9: Power steering pump rotor and vanes

A balanced pulley is pressed on the steering pump drive shaft. This pulley and shaft are belt-driven by the engine. A spring-loaded lip seal at the front of the pump housing prevents fluid leaks between the pump shaft and the housing. The oblong pump reservoir is made from steel or plastic. A large o-ring seals the front of the reservoir to the pump housing Figure 4.10.

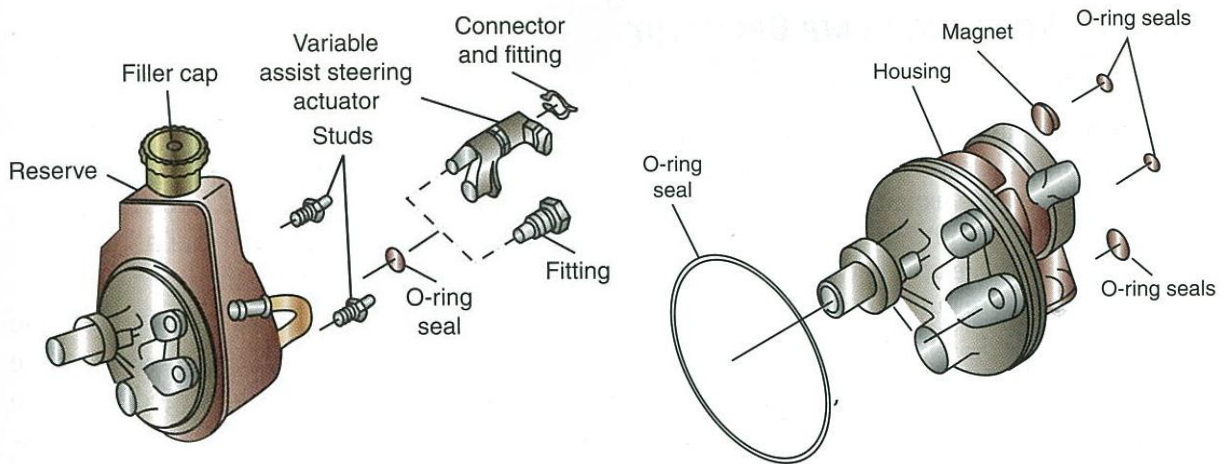


Figure 4.10: Power steering pump and reservoir

Smaller O-rings seal the bolt fittings on the back of the reservoir. The combination cap and dipstick keeps the fluid reserve in the pump and vents the reservoir to the atmosphere. Some power steering pumps have a variable assist steering actuator in the

back of the pump housing. The PCM operates this actuator to provide increased steering assist at low vehicle speed.

The rotating components inside the pump housing include the shaft and rotor with the vanes mounted in the rotor slots. A seal between the output shaft and the housing prevents oil leaks around the shaft. As the pulley drives the pump shaft, the vanes rotate inside an elliptically shaped opening in the cam ring. The cam ring remains in a fixed position inside the pump housing. A pressure plate is installed in the housing behind the cam ring Figure 4.11.

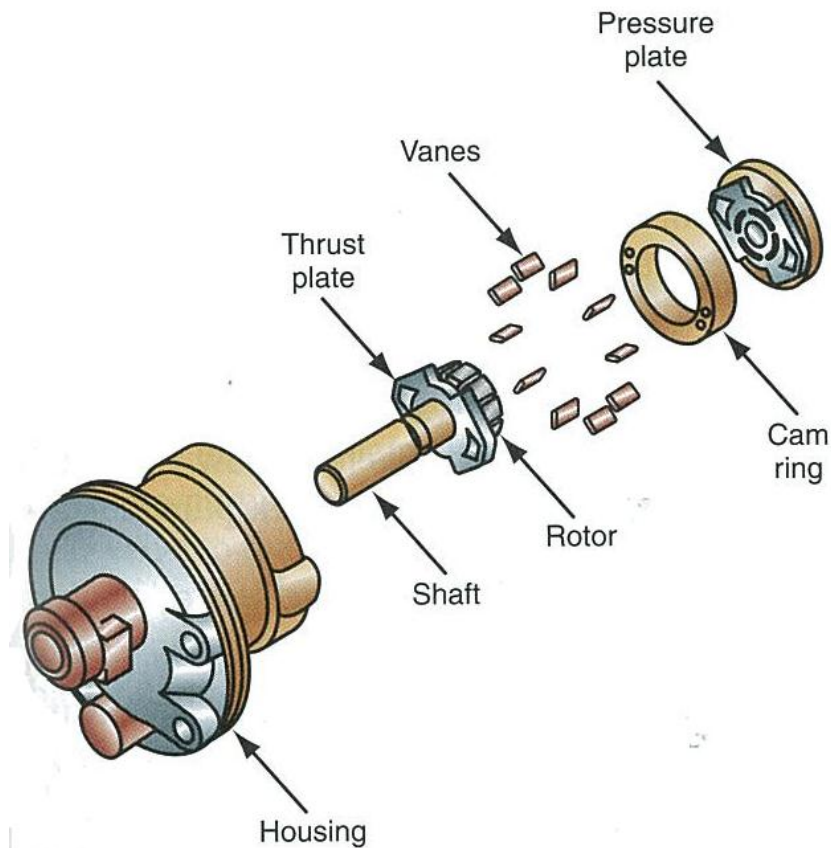


Figure 4.11: power steering pump housing with shaft and rotor, vanes, cam ring, and pressure plate.

A spring is positioned between the pressure plate and the end cover, and retaining ring holds the end cover in the pump housing. The flow control valve is mounted in the pump housing, and a magnet is positioned on the pump housing to pick up metal filings rather than allowing them to circulate through the power steering system Figure 4.12.

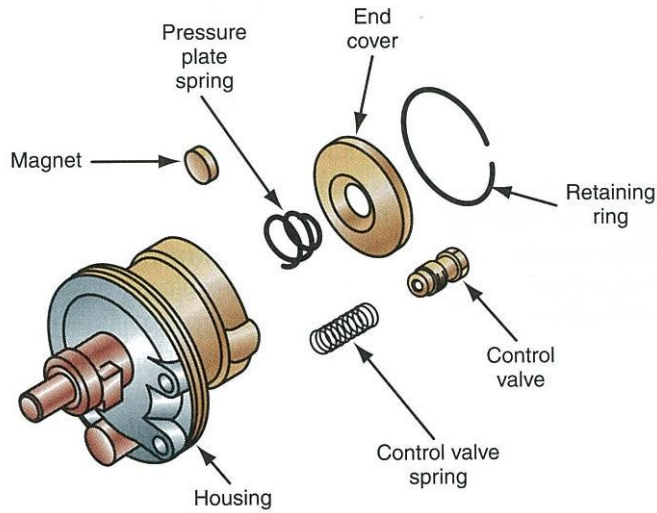


Figure 4.12: power steering pump housing assembly with end cover, flow control valve, and magnet.

The flow control valve is a precision-fit valve controlled by spring pressure and fluid pressure. Any dirt or roughness on the valve results in erratic pump pressure. The flow control valve contains a pressure relief valve Figure 4.13. High-pressure fluid is forced past the control valve to the outlet fitting. A high-pressure hose connects the outlet fitting to the inlet fitting on the steering gear. A low-pressure hose returns the fluid from the steering gear to the inlet fitting in the pump reservoir.

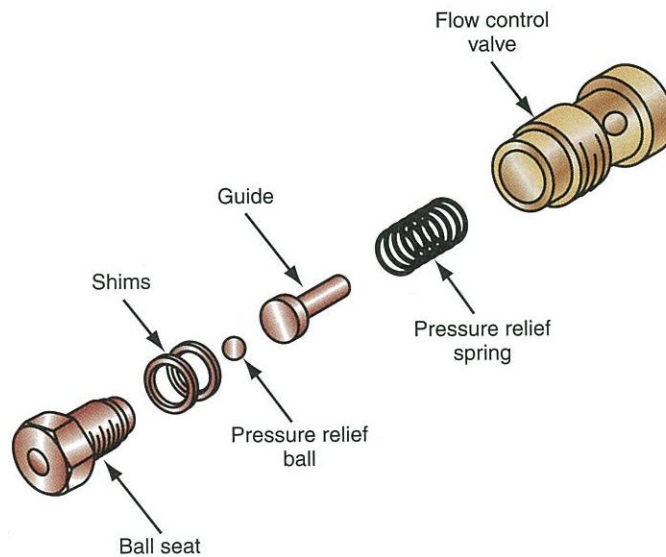


Figure 4.13: Flow control valve

4.3.1 Power Steering Pump Operation

As the belt rotates the rotor and vanes inside the cam ring, centrifugal force causes the vanes to slide out of the rotor slots. The vanes follow the elliptical surface of the cam. When the area between the vanes expands, a low-pressure area occurs between the vanes and fluids flows from the reservoir into the space between the vanes shrinks and the fluid is pressurized.

High pressure fluid is forced into two passages on the thrust plate. These passages reverse the fluid direction. Fluid is discharged through the cam crossover passages and pressure plate openings to the high pressure cavity and flow control valve. The fluid is discharged from the flow control valve through the outlet fitting Figure 4.14. though most of the fluid is discharged from the pump, some fluid returns to the bottom of the vanes past the flow control valve and through the bypass passage.

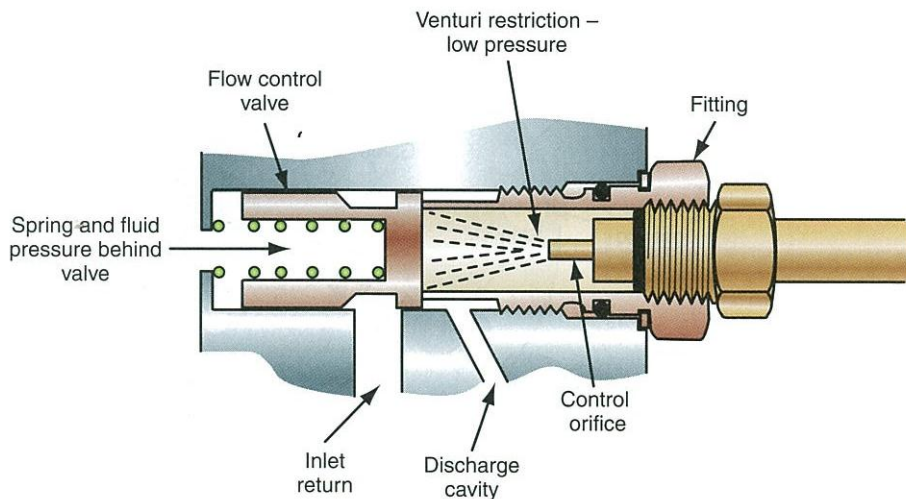


Figure 4.14: power steering pump fluid flow to control valve and outlet fitting.

A machined venturi orifice is located in the outlet fitting. Fluid passage applies pressure from the venturi area to the spring

4.3.2 Power Steering Pump Operation at Idle Speed

At idle speed with the wheels straight ahead, the flow of fluid from the pump to the steering gear is relatively slow. Under this condition, the steering gear valve is positioned

so the fluid discharged from the pump is directed through the valve and the low-pressure hose to the pump vane inlet. With low fluid flow, the pressure is higher in the venturi and control orifice. This higher pressure is applied to the spring side of the flow control valve and helps the valve spring keep this flow control valve closed figure 4.15. Under this condition, pump pressure remains low, and all the fluid is discharged from the pump through the steering gear valve and back to the pump inlet.

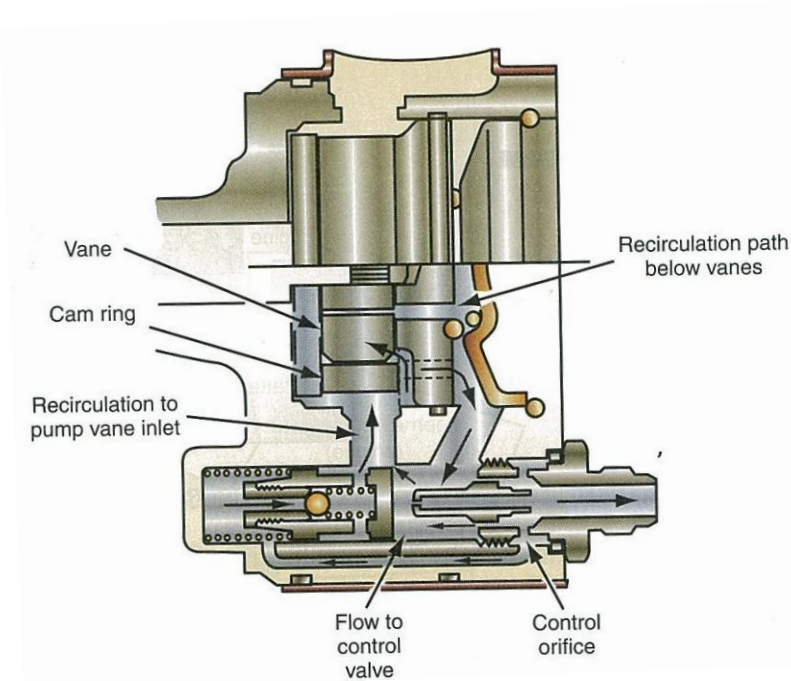


Figure 4.15: Flow control valve operation under various conditions.

4.3.3 Power steering pump operation at higher engine speeds

When engine speed is increased, the power steering pump delivers more fluid than the system requires. This increase in fluid flow creates a pressure decrease in the outlet fitting venturi. This pressure reduction is sensed at the spring side of the flow control valve, which allows the pump discharge pressure to force the flow control valve partially open. Under this condition, the excess fluid from the pump is routed past the flow control valve to the pump inlet. If the steering wheel is turned, the fluid discharged from the pump rushes into the pressure chamber in the steering gear.

4.3.4 Power steering pump operation during pressure relief

If the steering wheel is turned fully in either direction until the steering linkage contacts the steering stops, the rack piston is stop. Under this condition, pump pressure could become extremely high and damage hoses or other components. When the rack piston stops, the flow from the pump decreases, but the high pump pressure is still directed through the steering gear valve to the rack piston. Since the flow of fluid through the venturi and control orifice is reduced, a higher pressure is present in this area. At the predetermined pressure, the pressure relief ball in the center of the flow control valve is unseated and the flow control valve moves to the wide-open position. This action allows some of the high pressure in the steering system to return to the pump inlet, which limits pump pressure to a maximum safe value.

4.4 Power recirculating ball steering gears

4.4.1 Design

The ball nut and pitman shaft sector are similar in manual and power recirculating ball steering gears. In the power steering gear, a torsion bar is connected between the steering shaft and the worm shaft. Since the front wheels are resting on the road surface, they resist turning, and the parts attached to the worm shaft also resist turning. This turning resistance causes torsion bar twist when the wheels are turned, and this twist is limited to a predetermined amount. The worm shaft is connected to the rotary valve body, and the torsion bar pin also connects the torsion bar to the worm shaft. The upper end of the torsion bar is attached to the steering shaft and wheel. A stub shaft is mounted inside the rotary valve and a pin connects the outer end of this shaft to the torsion bar. The pin on the inner end of the stub shaft is connected to the spool valve in the center of the rotary valve Figure 4.16.

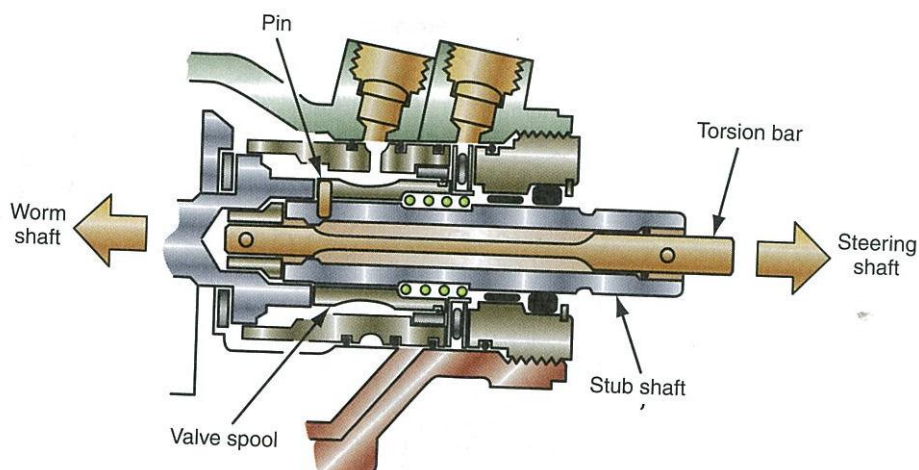


Figure 4.16: Torsion bar and stub shaft

4.4.2 Operation

When the car is driven with the front wheels straight ahead, oil flows from the power steering pump through the spool valve, rotary valve, and low-pressure return line to the pump inlet Figure 4.17. In the straight-ahead steering gear position, oil pressure is equal on both sides of the recirculating ball piston, and the oil acts as a cushion that prevents road shocks from reaching the steering wheel.

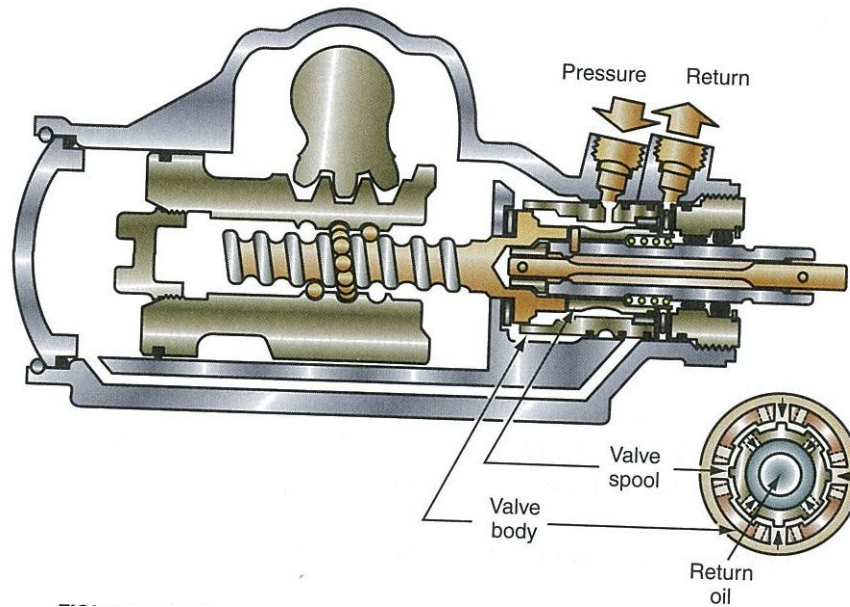


Figure 4.17: Power steering gear fluid flow with the wheels straight ahead.

If the driver makes a left turn, torsion bar twist moves the valve spool inside the rotary valve body so that oil flow is directed through the rotary valve to the left-turn holes in the spool valve Figure 4.18. Since power steering fluid is directed from these left-turn holes to the upper side of the recirculating ball piston Figure 4.19, this hydraulic pressure on the piston assists the driver in turning the wheels to the left.

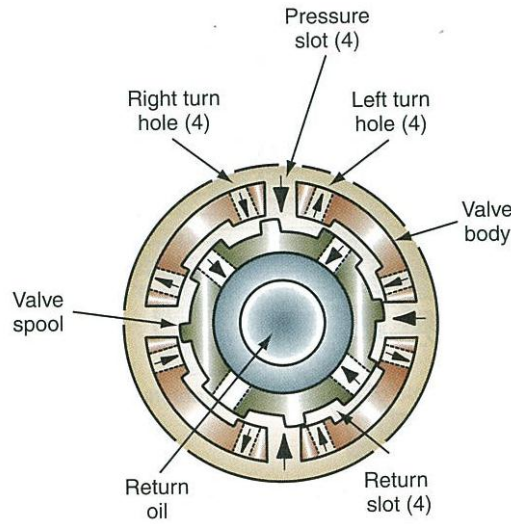


FIGURE 11-7 Spool valve position during a left turn.

Figure 4.18: Spool valve position during a left turn.

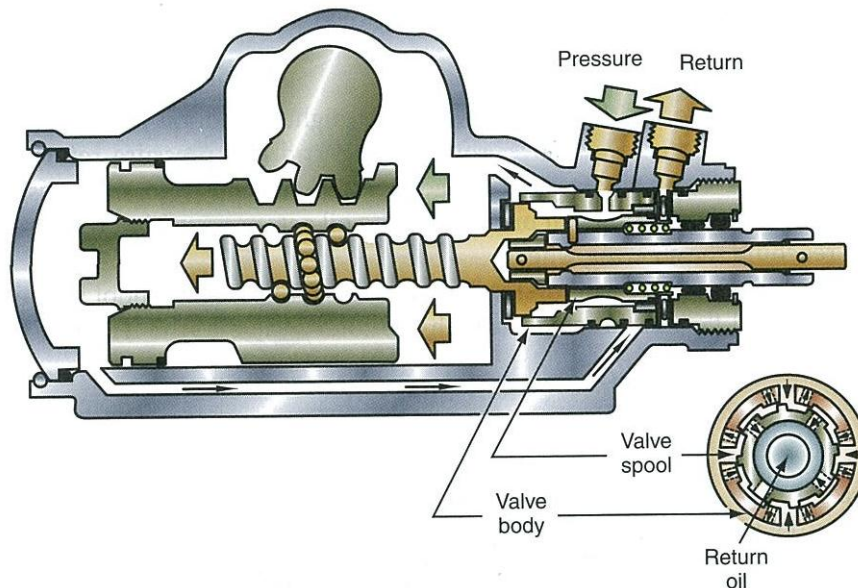


Figure 4.19: Power steering gear fluid flow during a left turn.

When the driver makes a right turn, torsion bar twist moves the spool valve so that oil flows through the spool valve, rotary valve, and passage in the housing to the pressure chamber at the lower end of the ball nut piston Figure 4.20. During a right turn, hydraulic pressure applied to the lower end of the recirculating ball piston helps the driver turn the wheels.

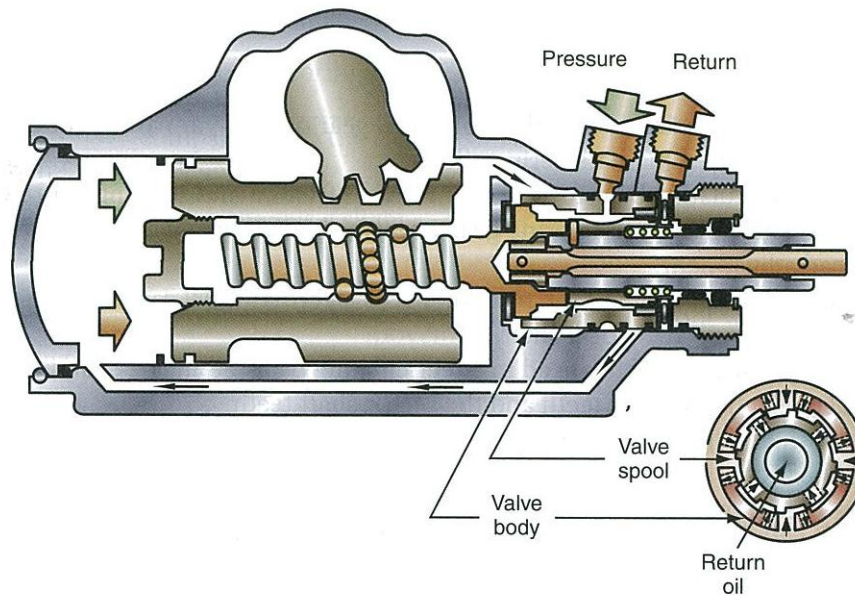


FIGURE 11-9 Power steering gear fluid flow during a right turn.

Figure 4.20: Power steering gear fluid flow during a right turn.

During a turn, if a front wheel strikes a bump and the front wheels are driven in the direction opposite the turning direction, the recirculating ball piston tends to move against the hydraulic pressure and force oil back out the pressure inlet port. This action would create a kickback on the steering wheel, but a poppet valve in the pressure inlet fitting closes and prevents kickback action.

Power rack and pinion steering gears

Design

A power-assisted rack and pinion steering gear uses the same basic operating principles as a manual rack and pinion steering gear, but in the power-assisted steering gear, hydraulic fluid pressure from the power steering pump is used to reduce steering effort. A rack piston is integral with the rack, and this piston is located in a sealed chamber in the steering gear housing. Hydraulic fluid lines are connected to each end of this chamber, and rack seals are positioned in the housing at ends of the chamber. A seal is also located on the rack piston Figure 4.21.

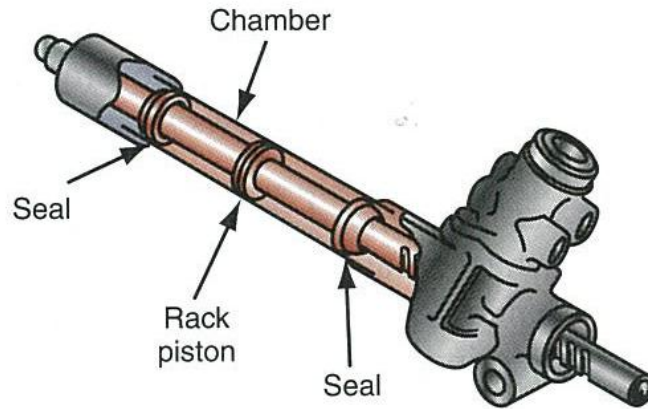


Figure 4.21: Hydraulic chamber in a power rack and pinion steering gear

Operation

When a driver is completing a left turn, fluid is pumped into the left side of the fluid chamber and exhausted from the right chamber area. This hydraulic pressure on the left side of the rack piston helps the pinion move the rack to the right Figure 4.22.

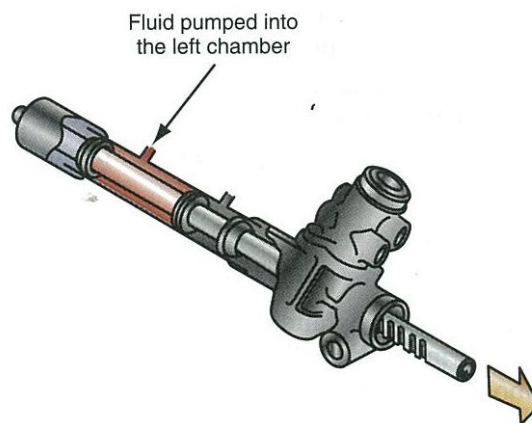


Figure 4.22: Rack movement to the right

When a right turn is made, fluid is pumped into the right side of the fluid chamber, and fluid flows out of the left end of the chamber. Thus, hydraulic pressure is exerted on the right side of the rack piston, which assists the pinion gear in moving the rack to the left Figure 4.23. Since the steering gear is mounted behind the front wheels, rack movement to the left is necessary for a right turn, whereas rack movement to the right causes a left turn.

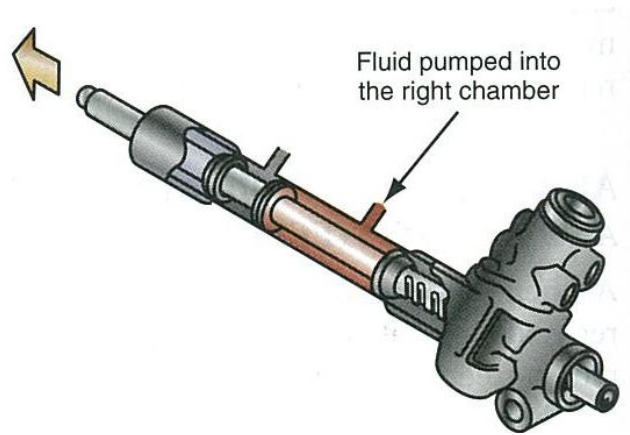


Figure 4.23: Rack movement to the left

Rotary valve and spool valve operation

Fluid direction in the steering gear is controlled by a rotary valve attached to the pinion assembly Figure 4.24. A sub shaft on the pinion assembly is connected to the steering shaft and wheel. The pinion is connected to the stub shaft through a torsion bar that twists when the steering wheel is rotated and springs back to the center position when the wheel is released. A rotary valve body contains an inner spool valve that is mounted over the torsion bar on the pinion assembly.

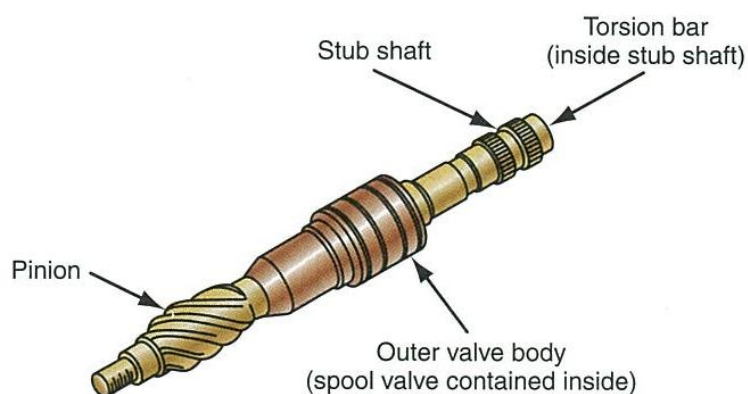


Figure 4.24: Pinion assembly for a power rack and pinion steering gear.

When the front wheels are in the straight-ahead position, fluid flows from the pump through the high-pressure hose to the center rotary valve, body passage. Fluid is then routed through the valve body to the low-pressure return hose and the pump reservoir Figure 4.25.

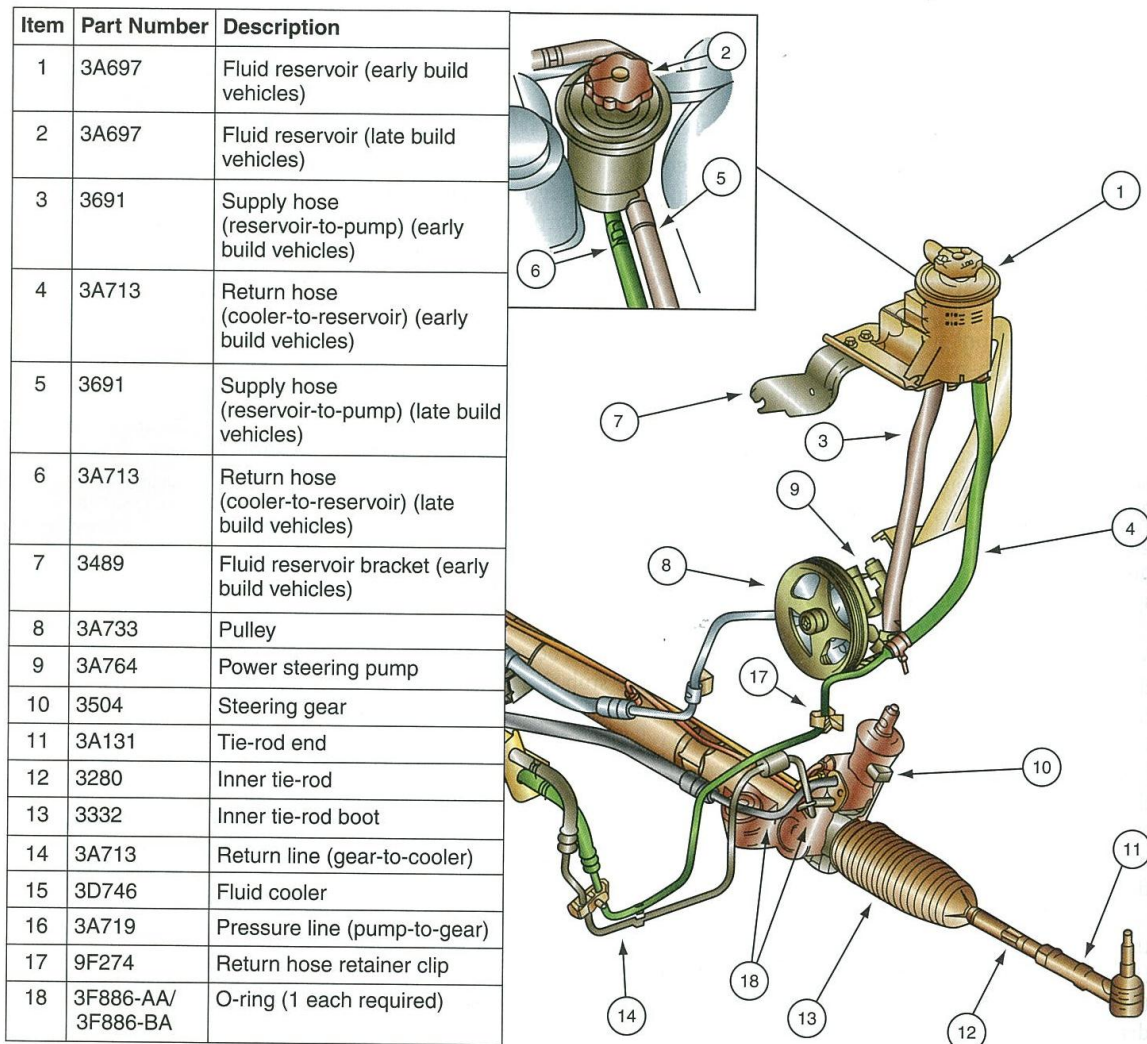


FIGURE 12-5 Power rack and pinion steering gear with connecting hoses and lines.

Figure 4.25: Power rack and pinion steering gear with connecting hoses and lines.

Many power steering systems contain a fluid cooler connected in the high-pressure hose between the pump and the steering gear. The fluid cooler is like a small radiator. Air flows through the fins on the cooler and cools the fluid flowing through the internal cooler passages. Some power steering systems have a remote fluid reservoir connected in the low pressure hose between the steering gear and the pump Figure 4.25. Many power steering systems have a fluid filter, and this filter is often mounted in the remote reservoir.

Teflon rings or O-rings seal the rotary valve ring lands to the steering gear housing. A lot of force is required to turn the pinion and move the rack because of the vehicle weight on the front wheels. When the driver turns the wheel, the stub shaft is forced to turn. However, the pinion resists turning because it is in mesh with the rack,

which is connected to the front wheels. This resistance of the pinion to rotation results in torsion bar twisting. During this twisting action, a pin on the torsion bar moves the spool valve with a circular motion inside the rotary valve. If the driver makes a left turn, the spool valve movement aligns the inlet center rotary valve passage with the outlet passage to the left side of the rack piston. Therefore, hydraulic fluid pressure applied to the left side of the rack piston assists the driver in moving the rack to the right.

When a right turn is made, twisting of the torsion bar moves the spool valve and aligns the center rotary valve passage with the outlet passage to the right side of the rack piston Figure 4.26. Under this condition, hydraulic fluid pressure applied to the rack piston helps the driver move the rack to the left. The torsion bar provides a feel of the road to the driver.

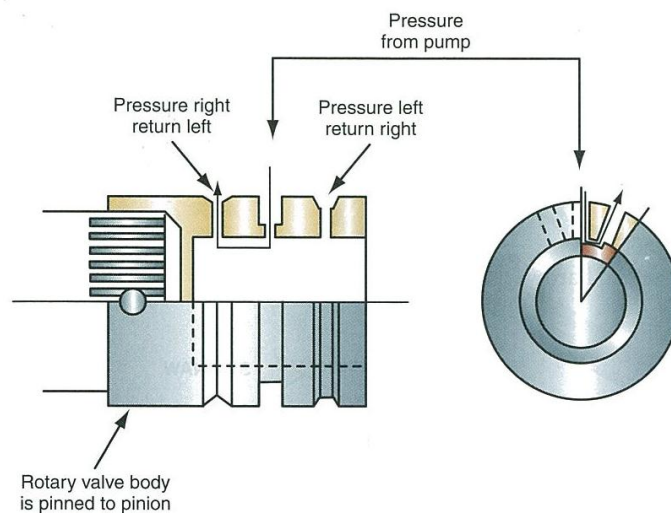


Figure 4.26: Spool valve movement inside the rotary valve

When the steering wheel is released after a turn, the torsion bar centers the spool valve and power assistance stops. If hydraulic fluid pressure is not available from the pump, the power steering system operates like a manual system, but steering effort is higher. When the torsion bar is twisted to a designed limit, tangs on the stub shaft engage with drive tabs on the pinion. This action mechanically transfers motion from the steering wheel to the rack front wheels. Since hydraulic pressure is not available on the rack piston, greater steering effort is required. If a front wheel raises going over a bump or drops into a hole, the tie-rod pivots along with the wheel. However, the rack and tie-rod still maintain the left-to-right wheel direction.

The rack boots are clamped to the housing and the rack. Since the boots are sealed and air cannot be moved through the housing, a breathe tube is necessary to move air from one boot to the other when the steering wheel is turned **Figure 4.27**. This air movement through the vent tube prevents pressure changes in the bellows boots during a turn.

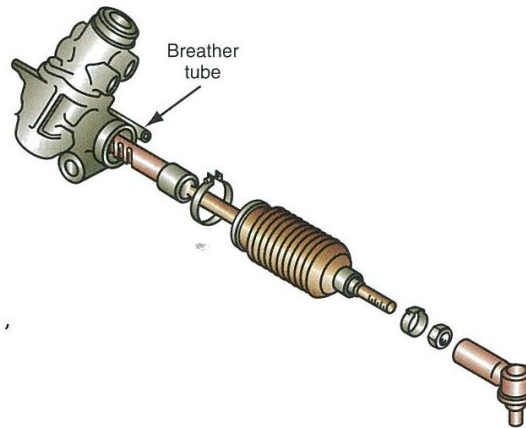


FIGURE 12-7 Breather tube and boot.

Figure 4.27: Breather tube and boot

Types of power rack and pinion steering gears

Power rack and pinion gear

Many vehicles have a rack and pinion steering gear manufactured by Saginaw **Figure 4.28**. Some vehicles are equipped with a TRW rack and pinion steering gear. This type of steering gear is similar to the Saginaw gear except for the following differences:

1. Method of tie-rod attachment
2. Bulkhead oil seal and retainer
3. Pinion upper and lower bearing hardware

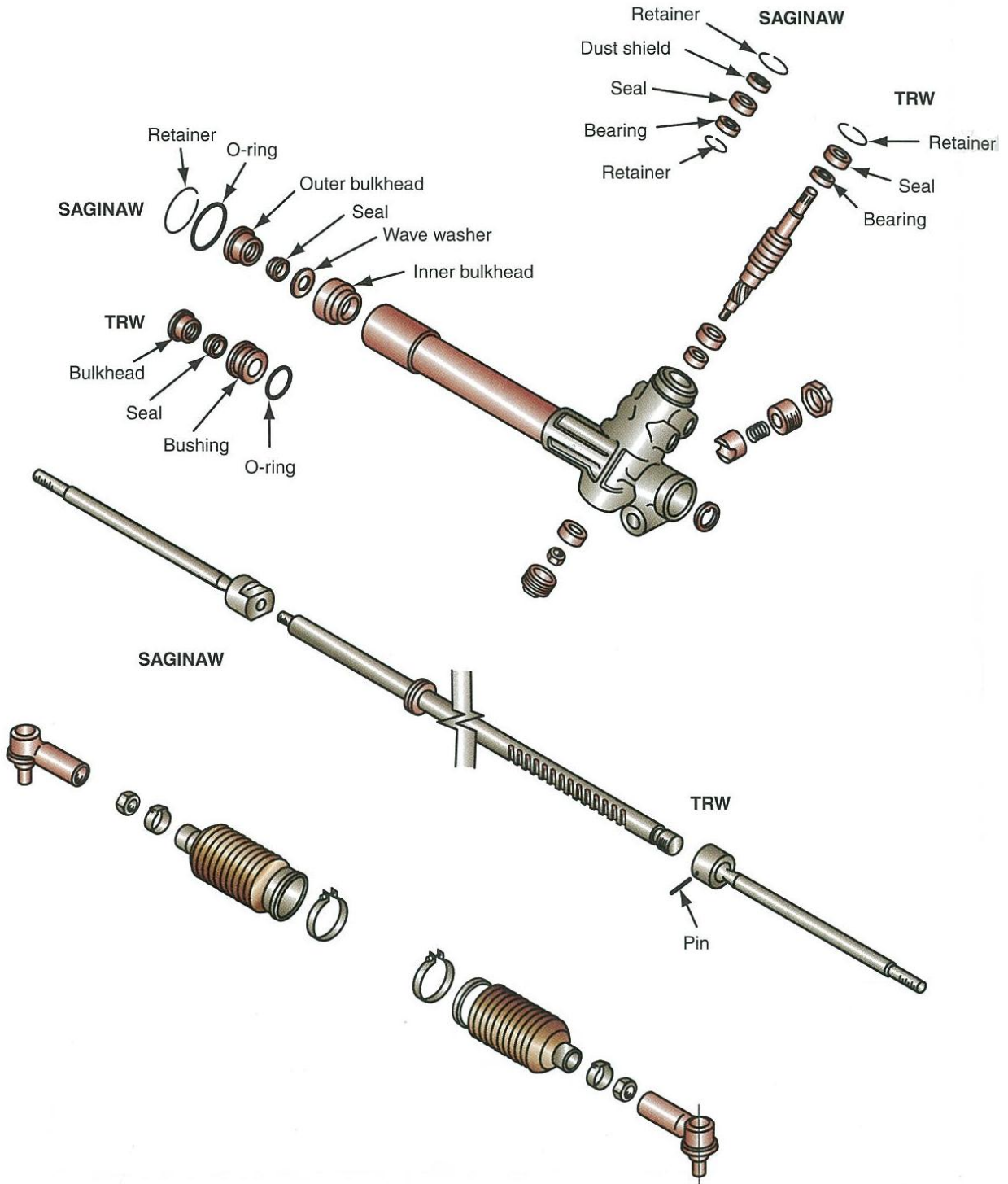


Figure 4.28: Saginaw and TRW power rack and pinion steering gear

On both the Saginaw and TRW power rack and pinion steering gears, the tie-rods are connected to the ends of the rack. This type of steering gear may be referred to as end take-off (ETO). On other power rack and pinion steering gears, the rack piston and cylinder are positioned on the right end of the rack and the tie rods are attached to a movable sleeve in the center of the gear Figure 4.29. this type of steering gear may called center take-off (CTO).

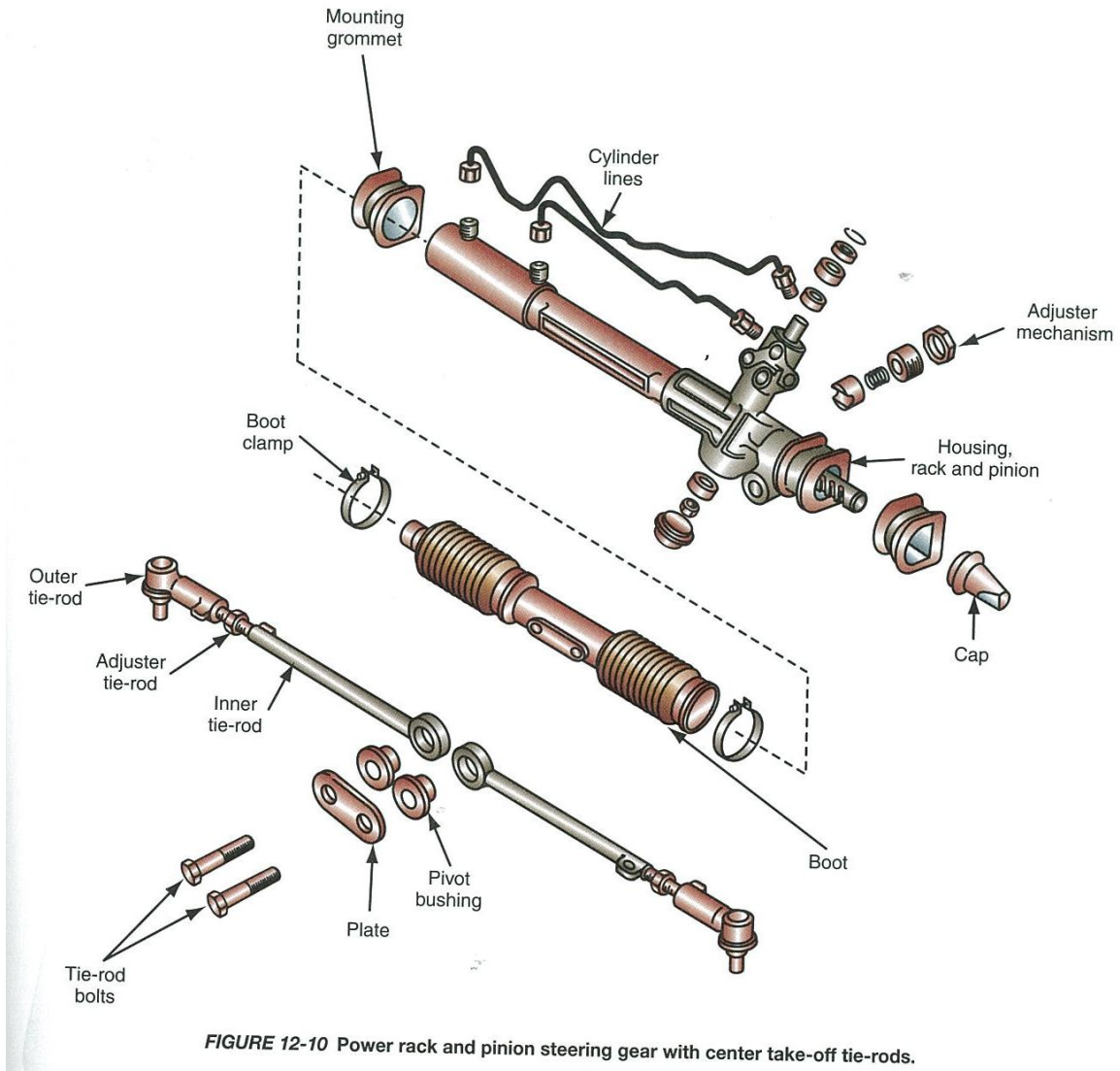
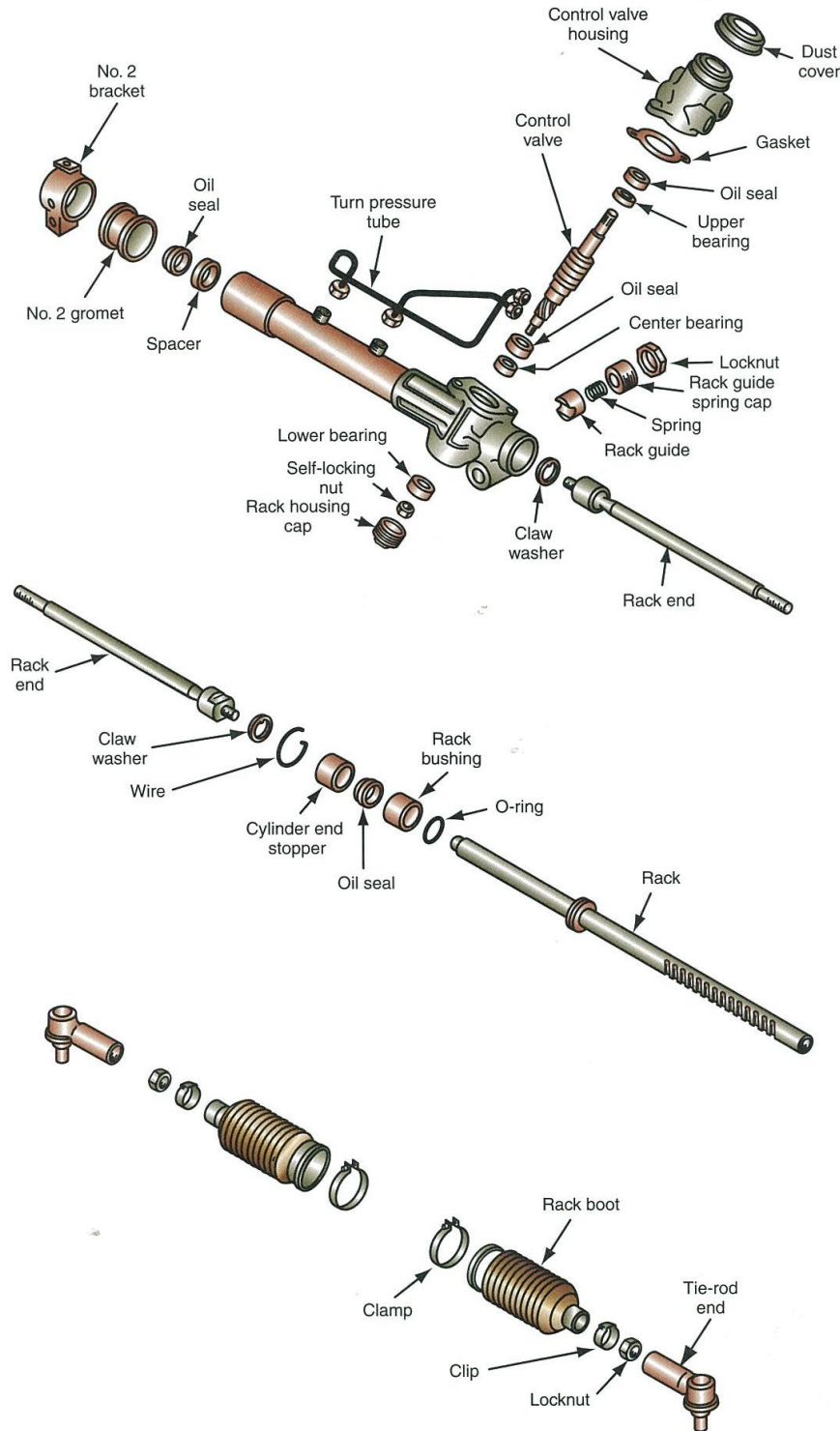


Figure 4.29: Power rack and pinion steering gear with center take-off tie-rods.

The Toyota power rack and pinion steering gear has a removable control valve housing surrounding the control valve and pinion shaft Figure 4.30. In this steering gear, claw washers are used to lock the inner tie-rod ends to the rack. Apart from these minor differences, the Toyota power rack and pinion gear is similar to the Saginaw and TRW gears.



4.30: Toyota power rack and pinion steering gear