



# **ASE 4 - Suspension & Steering**

## **Module 1 Steering Gears**

# Acknowledgements

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# Introduction

The purpose of this course is to provide technicians with knowledge of the components, function, and operation of GM steering systems.

In this course you will learn how to identify the characteristics of the:

- Steering systems used in GM vehicles
- Hydraulic system during power-assisted steering
- Variable effort steering (VES) system
- Systems and components that affect steering column service
- Various checks, tests, and tools used in diagnosing customer concerns, and

Servicing steering system components The Steering Service course consists of three Lessons and an end of course test.

The Lessons include:

- Basic Steering System Operation
- Power-Assisted Steering
- Variable Effort Steering

## Objectives

### NATEF Area IV

1. (P-3) Diagnose power steering gear (non-rack and pinion) binding, uneven turning effort, looseness, hard steering, and fluid leakage concerns; determine necessary action.
2. (P-3) Diagnose power steering gear (rack and pinion) binding, uneven turning effort, looseness, hard steering, and fluid leakage concerns; determine necessary action.
3. (P-3) Adjust manual or power non-rack and pinion worm bearing preload and sector lash.
4. (P-2) Diagnose power steering fluid leakage; determine necessary action.
5. (P-3) Test and diagnose components of electronically controlled steering systems using a scan tool; determine necessary action.

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## Lesson 1. Basic Steering System Operation

In this lesson, Basic Steering System Operation, the operating characteristics of the steering systems used in General Motors vehicles will be discussed.

This lesson consists of five sections and a lesson test.

The steering system allows the vehicle operator to control the position of the front wheels. In order to accomplish this control, the steering system uses several components between the steering wheel and the front wheels.

*In this lesson, we will discuss the function and operation of these components.*

There are several key factors that affect the performance of a steering system. One factor is the resistance to movement of various components of the steering system.

Components that resist movement include:

- The steering wheel
- The steering column
- The intermediate shaft
- The steering linkage

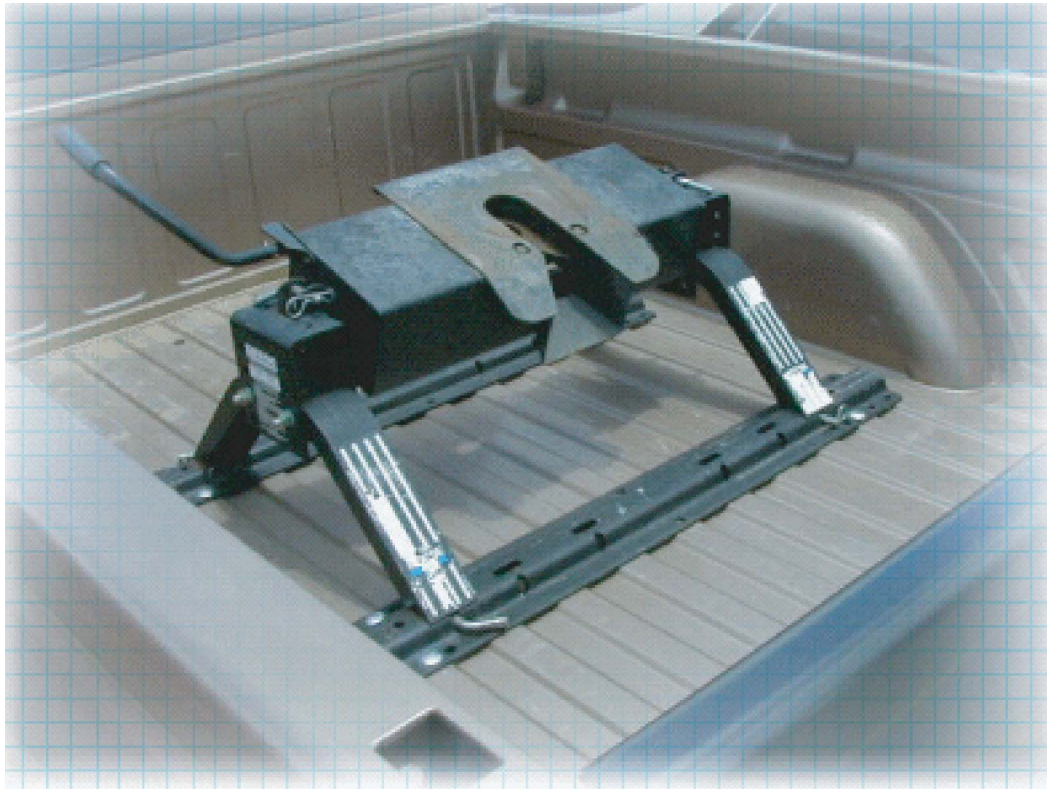
*The condition of the front and rear tires, such as worn tires, incorrect tire pressure, and improper alignment impact steering system performance.*

The amount of weight on the front axle directly affects steering system performance.

*The more weight, the harder the system must work to turn the wheels.*

In addition to the factors already discussed, the fifth-wheel and trailer plate in some medium duty trucks can also affect the performance of the steering system.

If the fifth-wheel and the trailer plate are not clean and well lubricated, the amount of effort required to steer the vehicle is increased.



*Figure 4-1, Trailer Plate*

The vehicle's front and rear suspension can also affect the steering system.

If the suspension is not correctly aligned and in good condition, the steering system will not function properly.

Finally, incorrect installation of components and damaged components negatively affect the steering system.

**It is critical that steering components be correctly installed and any damaged component be replaced. The vehicle's front and rear suspension can also affect the steering system.**

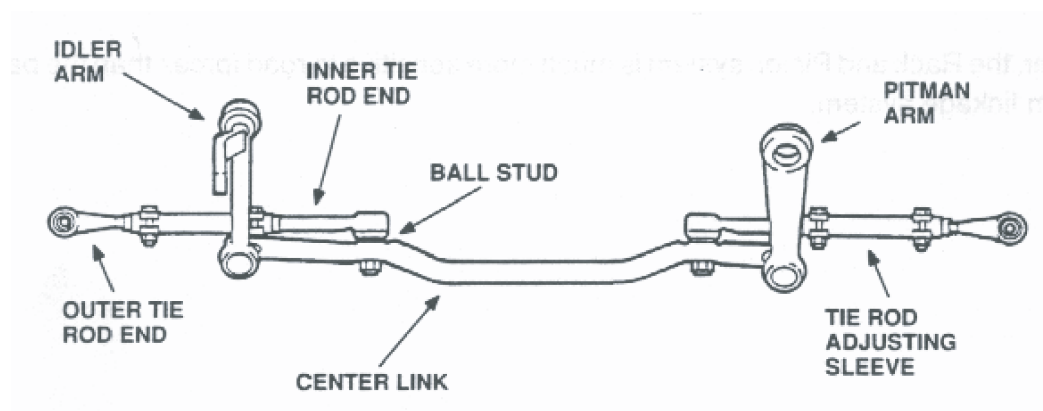
Let's review the components of the steering system.

The steering linkage connects the gearset to the steering arms.

The steering linkage includes:

- Pitman arm
- Center link
- Idler arm
- Tie rods

The steering arms attach the tie rods to the spindles and ball joints.



*Figure 4-2, Parallelogram System*

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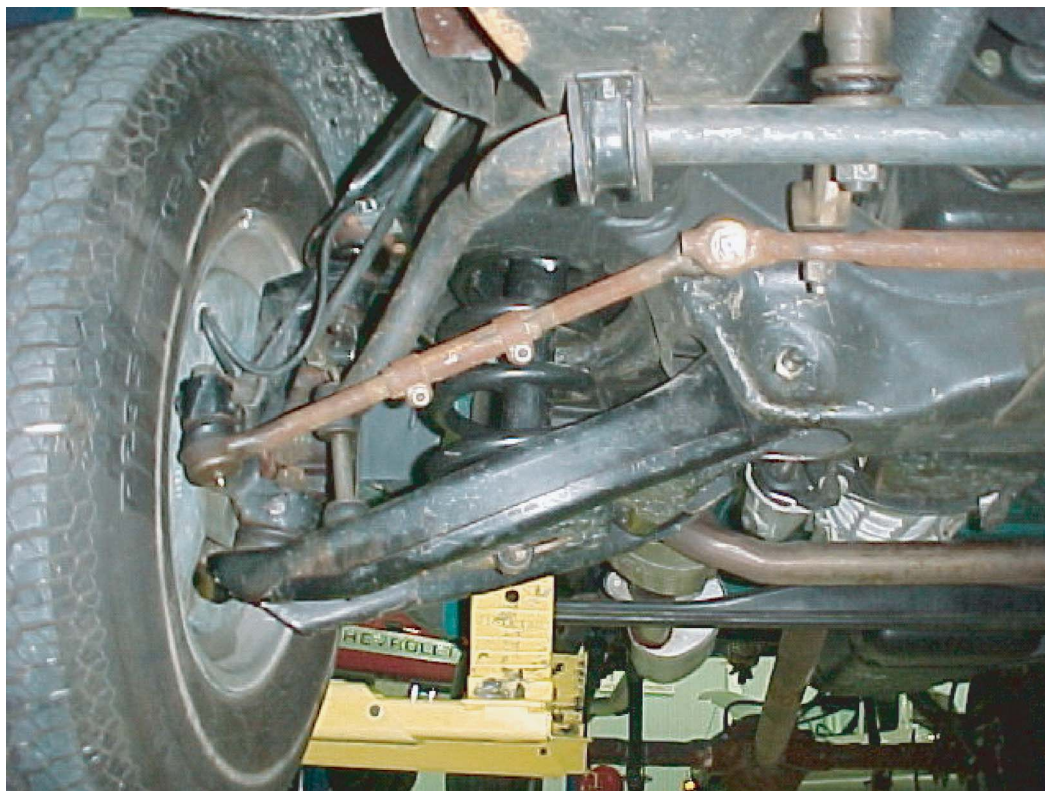


Figure 4-3,

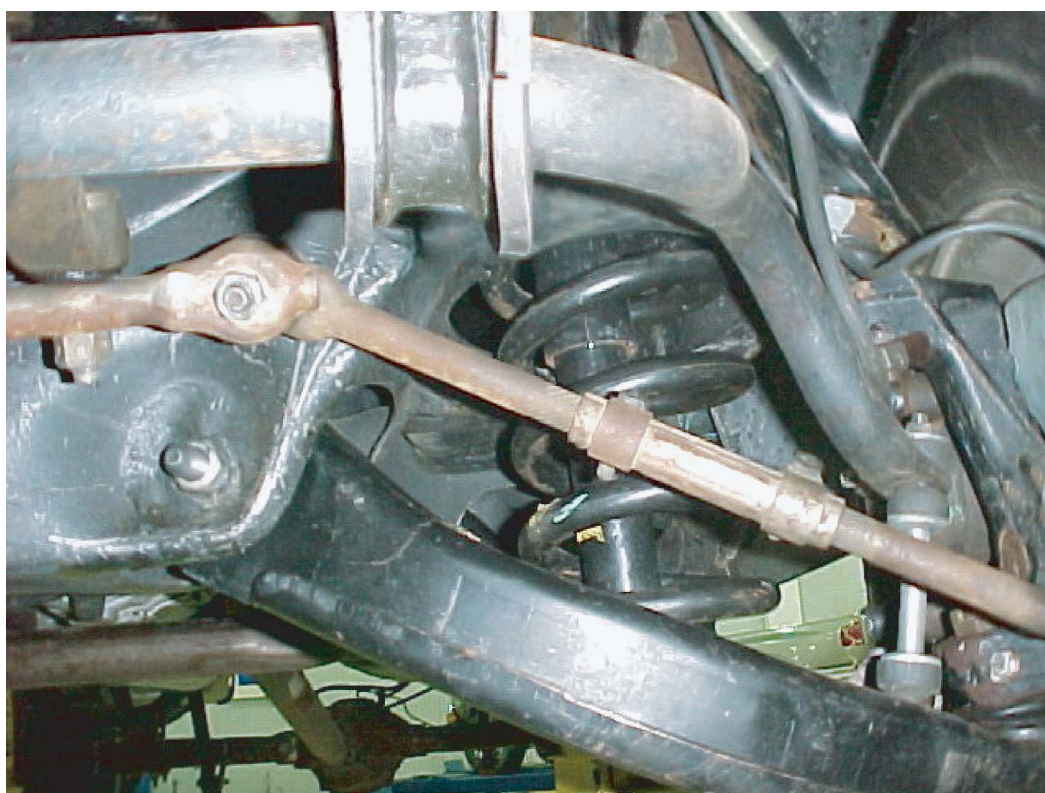


Figure 4-4,





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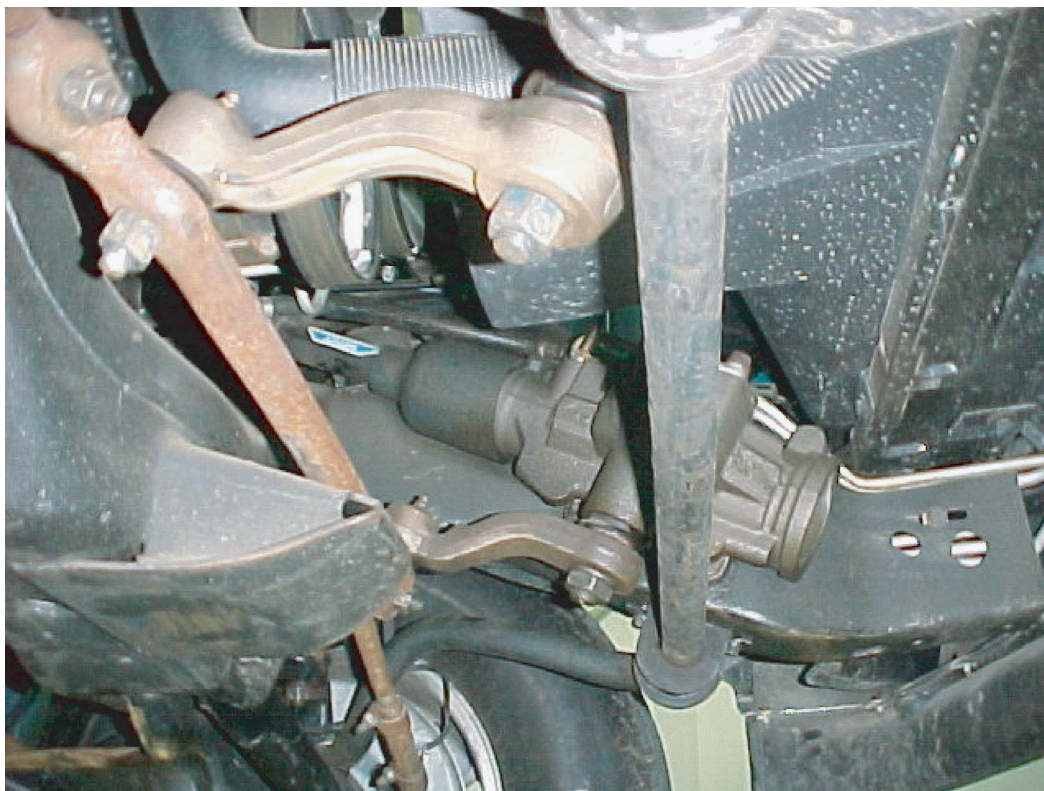


Figure 4-5,

*The movement of the steering arms changes the direction of the wheel.*

*The power steering pump and hoses enhance the driver's efforts, making steering the vehicle much easier.*

## Steering Gearset Function

Steering systems are generally categorized by the type of steering gearset.

The two main types of gearsets are:

- The rack and pinion gearset, and
- The integral gearset, also called the recirculating ball gearset.

*Both types of gearsets perform the same function.* They convert the circular motion of the steering wheel into the lateral motion that is required to position the front wheels

Both types of gearsets can be either manual or power assisted.

- The manual gearsets use the mechanical advantage of the steering wheel and the gears to assist the vehicle operator in moving the front wheels.

*The power assisted steering gearsets use hydraulic pressure to assist the vehicle operator.*

On the rack and pinion gearset, the tie rods are directly connected to the gearset. In general, rack and pinion gearsets are used on passenger cars.

The rack and pinion gearset has several advantages over the integral gearset for passenger cars.

- They are lighter weight for improved fuel economy;
- The space efficiency allows for tight design applications
- *The design is flexible enough to accommodate a wide range of vehicle specifications.*

The rack and pinion gearset is also compatible with front-wheel drive vehicle design. It is more responsive and provides more of a "road feel." In the integral gearset, a pitman arm connects the gearset to the steering linkage.



Figure 4-6,

*In general, integral gearsets are used in light and medium duty trucks.*

## Basic Power-Assisted Steering Function

Power-assisted steering reduces the amount of effort required to turn the steering wheel.

*This is especially helpful when the vehicle is not moving or is moving slowly. In these situations, there is more resistance between the tires and the road surface.*

Power-assisted steering uses hydraulic pressure to provide the assistance. The power steering pump provides the source of pressurized fluid and is driven by the engine through the pump pulley.

The pressurized fluid is sent to the gearset via a pressure hose and is returned to the pump through a return hose.

More information concerning power steering pumps and hoses is provided later in this course. In an integral gear system, the fluid acts against gearset components to provide the steering assist. In a rack and pinion system, the fluid is sent to a gearset that contains a valve body. The fluid is directed from the valve body to the rack housing moving a piston to provide the steering assist.

*The operation of integral gear and rack and pinion systems is covered in depth later in the course.*

This lesson will cover the mechanical operation of the rack and pinion steering system.

The main components include the:

- Steering wheel
- Steering and intermediate shaft
- Rack and pinion gearset
- Steering gear assembly
- Tie rods

The power flow through the rack and pinion gearset begins with the steering wheel turning the pinion of the gearset.

As the pinion is meshed with the rack gear, the rack gear moves laterally. The lateral motion of the rack gear is dependent upon the rotation of the pinion gear.

*As stated earlier, the rack and pinion gearset houses a valve body to direct the flow of the power steering fluid assisting in steering the vehicle.*

*The rack gear is connected to both tie rods. The movement of the rack gear controls the lateral movement of the tie rods and the position of the front wheels.*

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The rack gear is connected to both tie rods. The movement of the rack gear controls the lateral movement of the tie rods and the position of the front wheels

There are two rack and pinion design variations:

- End Take-Off (ETO), and
- Center Take-Off (CTO)

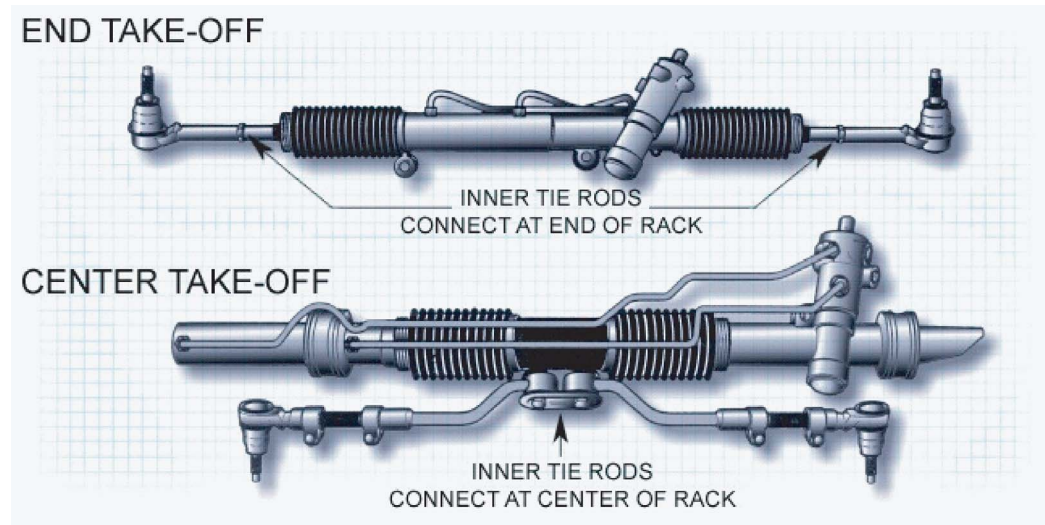


Figure 4-7, Rack and Pinion Designs

Both designs function the same and can be used with either manual steering or power assist systems.

*Rack and pinion operation and service for both ETO and CTO designs will be covered later in this lesson.*



## Integral Steering System

The components for the integral system include the:

- Steering wheel
- Steering and intermediate shaft
- Integral gearset
- Pitman arm
- Center link
- Idler arm
- Tie rods

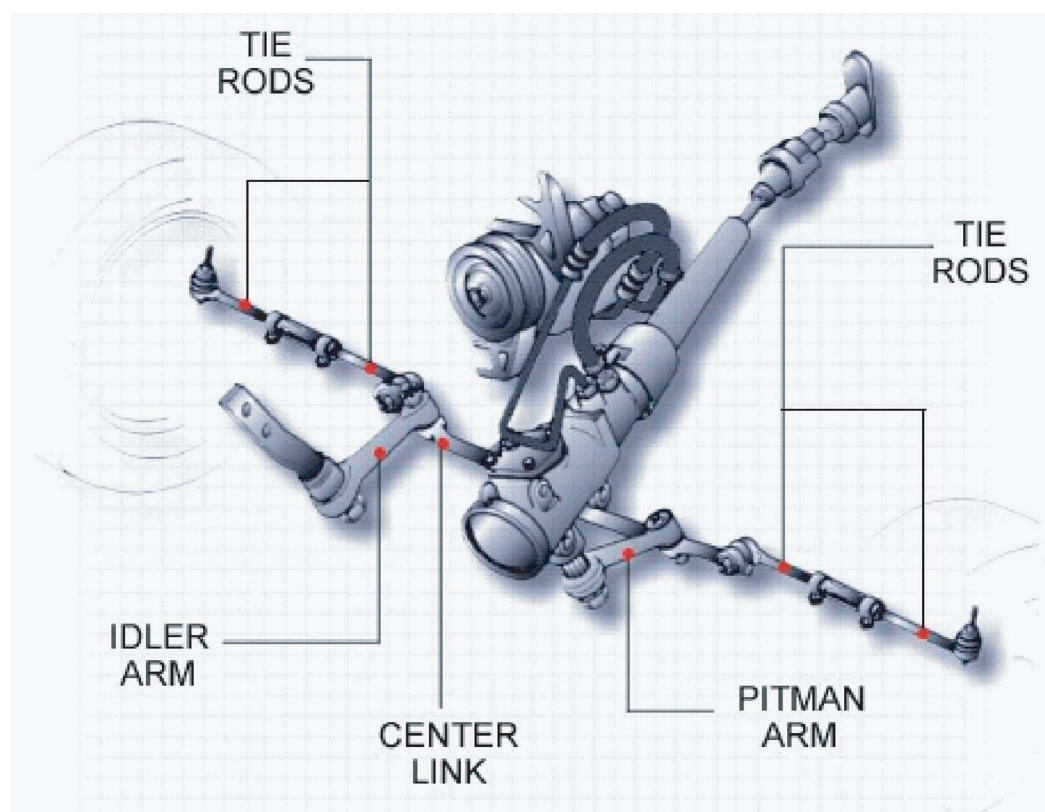


Figure 4-8, Integral Steering System



## Power Steering Pump and Hoses

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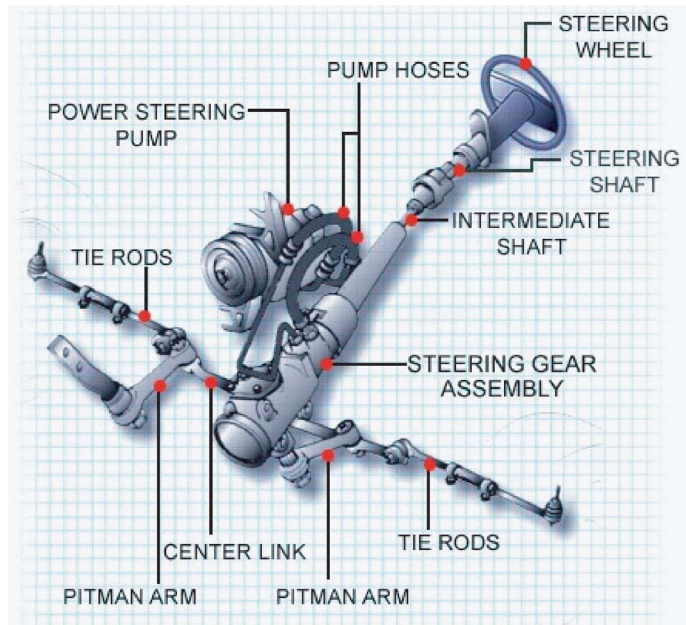


Figure 4-9, Power Steering Pump and Hoses

In a rack and pinion system, the fluid is sent to a gearset that contains a valve body. The fluid is directed from the valve body to the rack housing moving a piston to provide the steering assist.

Although the integral steering system has many of the same components as the rack and pinion steering system, the powerflow in the integral gearset is very different.

When the steering wheel is turned, it turns a wormshaft inside the gearset. The wormshaft, connected to a ball nut by ball bearings, moves the ball nut in a lateral motion.

The ball nut has gear teeth that are meshed with a sector gear. The sector gear, connected to the pitman arm by a shaft, positions the center link and tie rods and positions the front wheels.

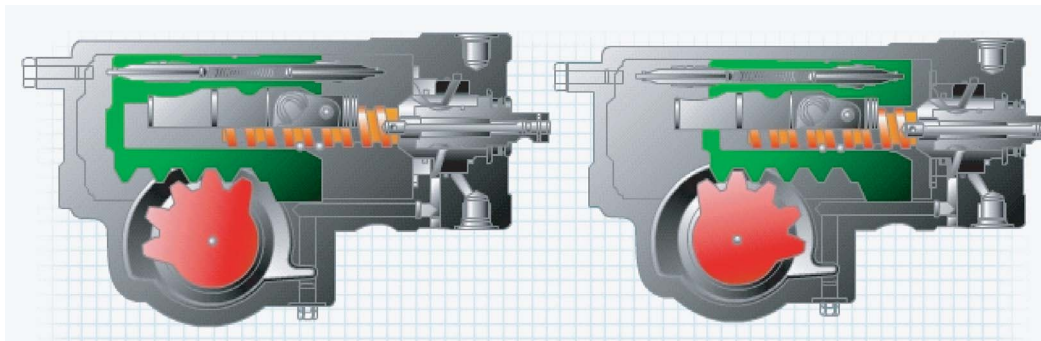


Figure 4-10,

The operation of integral gear and rack and pinion systems is covered in *depth later in the course*.



## Current Gearsets

GM currently uses both rack and pinion steering systems and integral gear steering systems on their vehicles

As was covered earlier, General Motors uses two types of Rack and Pinion Gearsets:

- The End Take-Off (ETO), and
- The Center Take-Off (CTO)

*Both gearsets operate the same. However, they have distinctly different appearances.*

Tie rods in an End Take-Off rack and pinion gearset are connected to the ends of the rack and pinion assembly.

The internal rack movement assisted by the power steering causes the tie rods to move.

*When viewed, the ends of the rack and pinion assembly appear to move in and out.*

The tie rods in a center take-off rack and pinion gearset are connected to the center of the rack and pinion assembly.

The rack movement, assisted by the power steering, causes the assembly to move back and forth causing the wheels to move.

*When viewed, the center of the assembly moves back and forth, causing tie rod movement.*

Three integral gear gearsets are used in GM vehicles. Two are for use with power steering, while one is a manual steering unit.

*Remember, prior to 1980 these gearsets were used in all GM vehicles and are still used in some rear wheel drive vehicles.*

Both power units have the steering gearset and the power steering valves housed in a single casing.

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This completes Lesson 1.

In this lesson, we reviewed:

- The key factors that affect the performance of a steering system
- The characteristics of steering gearsets
- Power-assisted steering
- Rack and pinion gearsets
- Integral gearsets

### Lesson 1 Test

1. What is a benefit of a rack and pinion gearset?
2. Which component of the rack and pinion steering system moves laterally to control the tie rods?
3. Which component of the integral gearset rotates to laterally position the ball nut?

## Lesson 2. Power-assisted Steering System Operation

This lesson discusses the operating characteristics of the hydraulic system during power-assisted steering.

This lesson is divided into eight sections and an end of lesson test.

An understanding of basic hydraulic principles is necessary to understand the operation of power-assisted steering.

Hydraulic fluid under pressure generates force. In a typical hydraulic system, the hydraulic force acts on a piston. Force can be applied to both sides of the piston.

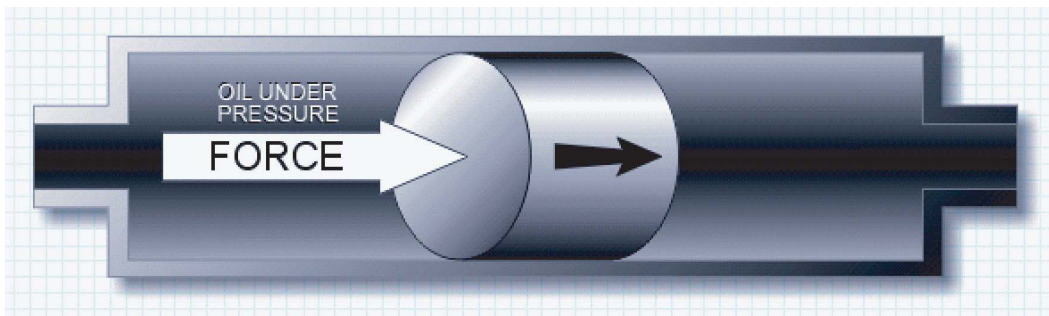


Figure 4-11, Hydraulic System

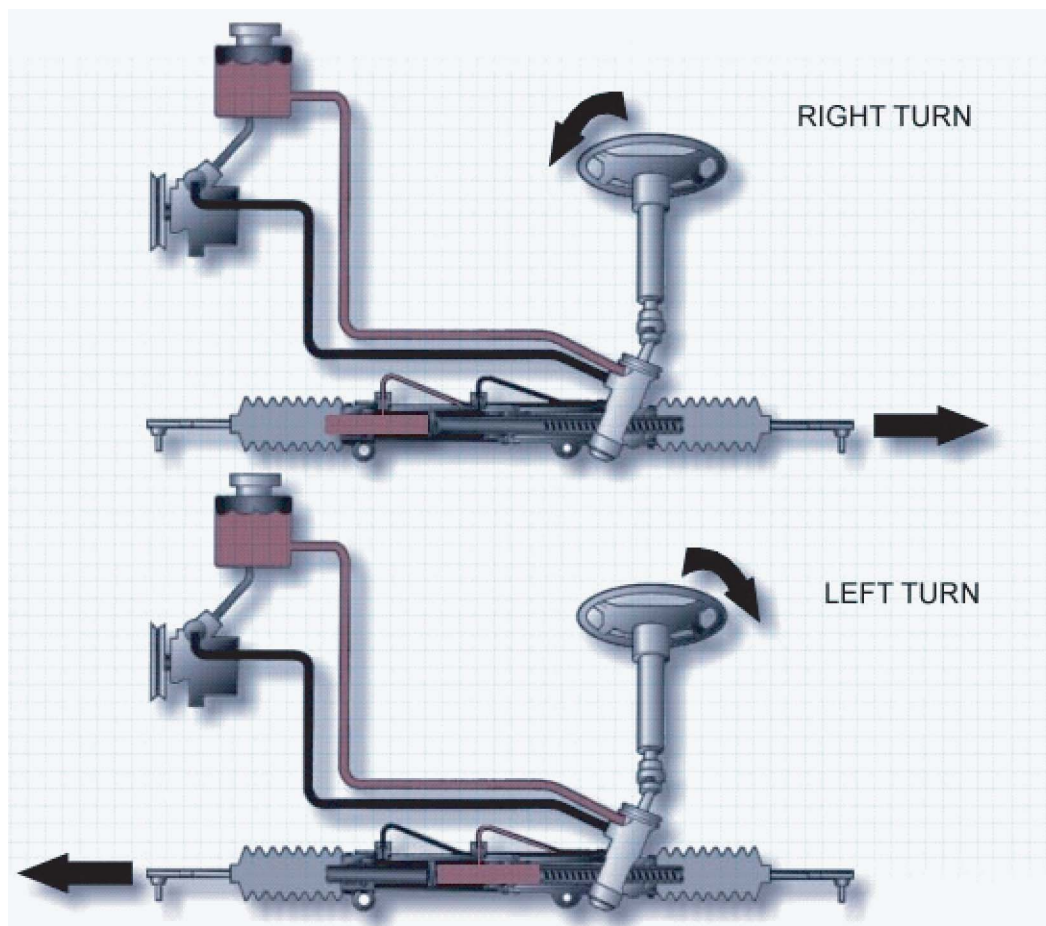


Figure 4-12,



In power steering systems hydraulic force assists in moving the front wheels.

When hydraulic force on one side of a piston is greater than the other, the piston moves towards the lesser force.

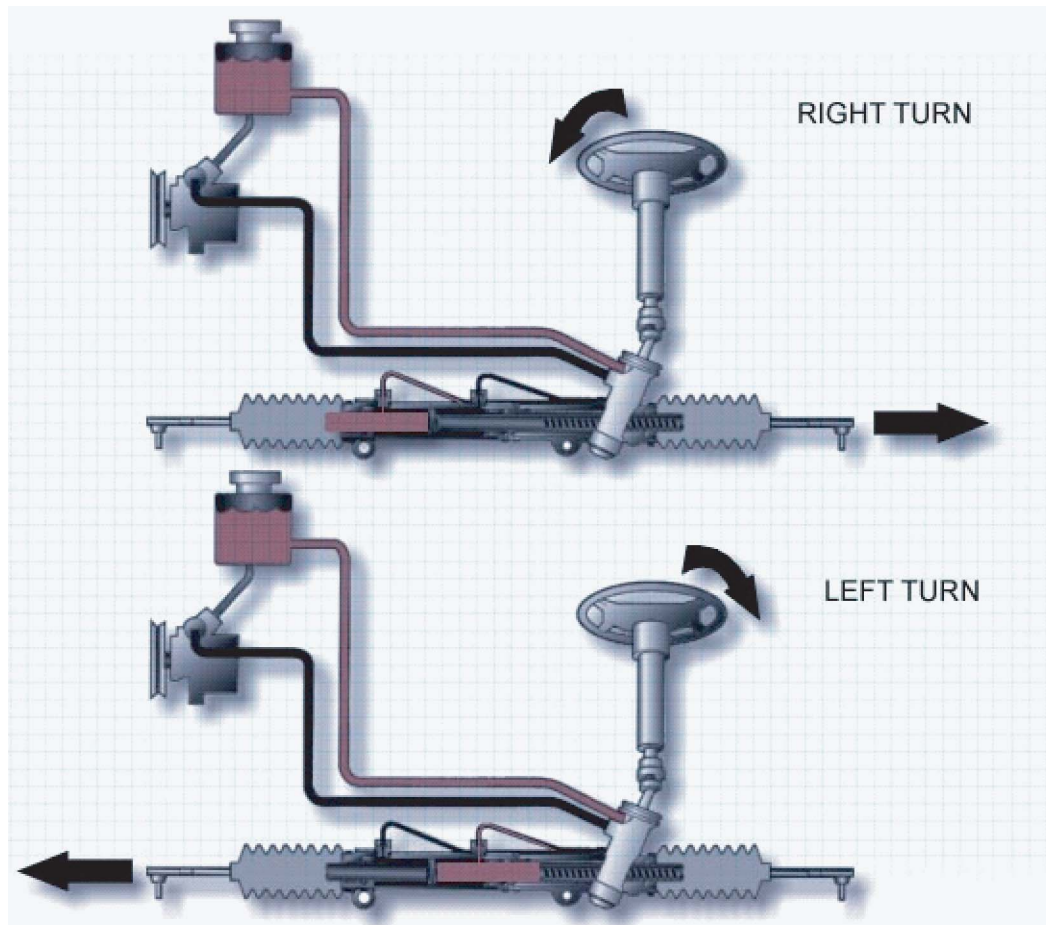


Figure 4-12,

The measurement of hydraulic force is expressed in pounds per square inch (PSI).

In this example, 100 pounds of force is exerted on 1 sq. inch of piston surface. This equates to 100 psi.

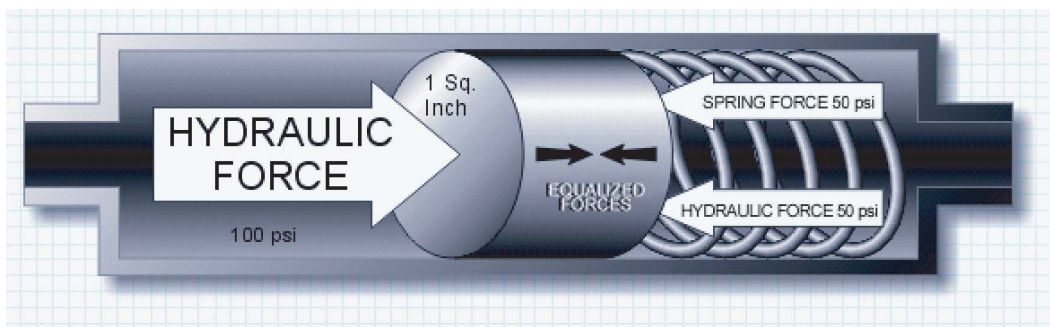


Figure 4-13,



GM power steering systems use assist springs to augment hydraulic force. The amount of force required to compress the spring is referred to as spring force.

Like hydraulic force, spring force is expressed in pounds per square inch. When used in a power steering system, the spring force is added to any hydraulic force on that side of the piston.

In the illustration, 50 psi of spring force and 50 psi of hydraulic force on the right side of the piston are the same as the 100 psi of hydraulic force on the left side of the piston. Therefore, the piston will not move.

The pressure of hydraulic fluid through a cylinder of uniform diameter is the same throughout the cylinder.

In a hydraulic system with no restrictions, the pressure is the same throughout the system.

A restriction in a hydraulic system creates a resistance to the flow. Pressure is increased before the restriction and, therefore, is decreased after the restriction. This difference in pressure is referred to as the pressure differential

The size of the restriction determines the pressure differential.

A large orifice acts as a small restriction and, therefore, will cause a slight pressure differential on either side of the restriction. A small orifice acts as a large restriction and will cause a greater pressure differential on either side of the restriction.

The pressure in a hydraulic system is based on the fluid output of the pump and the back pressure of the system.

Back pressure is the resistance of the system components to flow. Without the resistance to flow, the pump could not generate pressure

A low pump output provides a low flow rate and results in a low system pressure.

On the other hand, a high pump output provides a higher flow rate and thus results in a higher system pressure

If the flow in a hydraulic system stops, the pressure throughout the system will equalize.

Even if there is a restriction, the pressure equalizes on both sides of the restriction. Therefore, the restriction can only provide a pressure differential when there is fluid flow.

## Power Steering Pump Operation

Now that we have covered hydraulic principles, let's discuss how hydraulic pressure is generated in a power steering system.

The power steering pump, driven by the engine, generates the hydraulic pressure. GM power steering pumps fall into one of two categories:

- Submerged
- Non-submerged

P series submerged pumps combine the mechanical parts and the fluid reservoir in a single assembly.

These pumps do not require intake hoses, as the pump is completely submerged in the fluid.

Non-submerged pumps include:

- N
- T-C
- C-B series

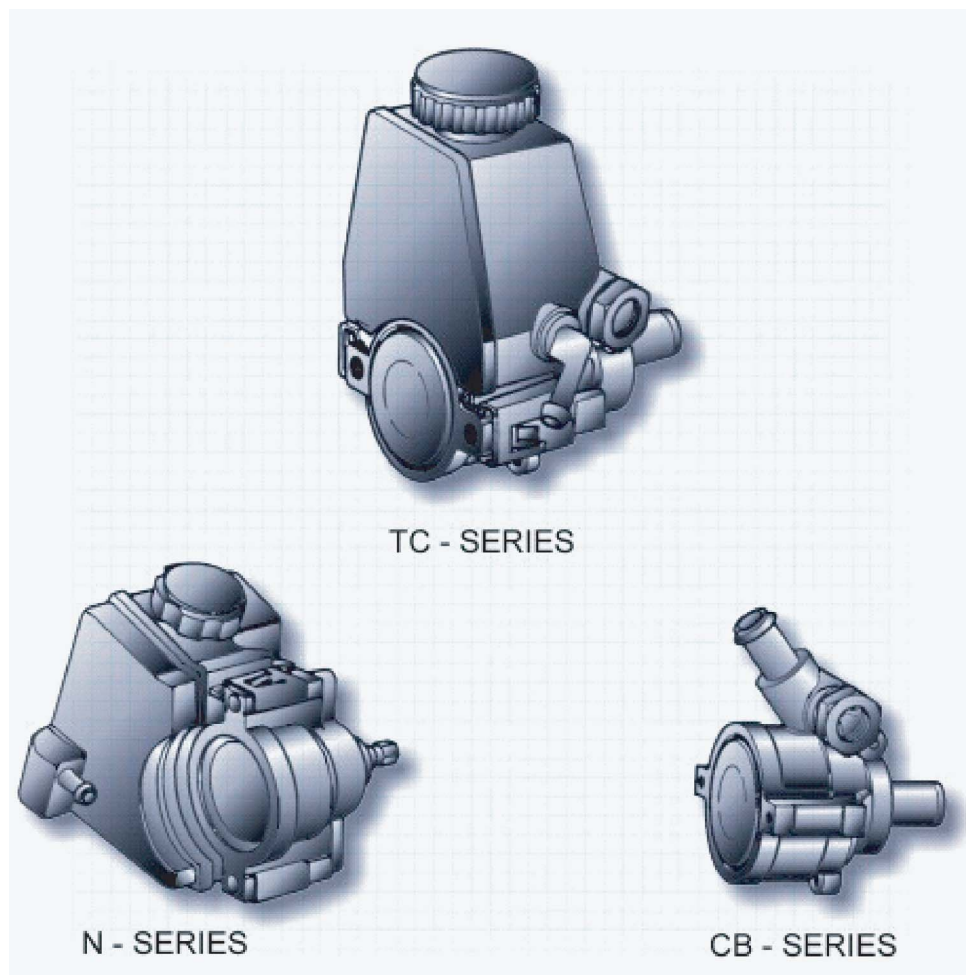


Figure 4-14, Power Steering Pump Operation

They have a separate, reservoir, which may be attached to the pump or mounted, in a remote location.

An intake hose is required for these pumps, since the pump is not submerged in the fluid

The major components of the power steering pump are:

- Pump body
- Pump ring
- Rotor
- Vanes or rollers

The rotor is the component that is driven by the engine.

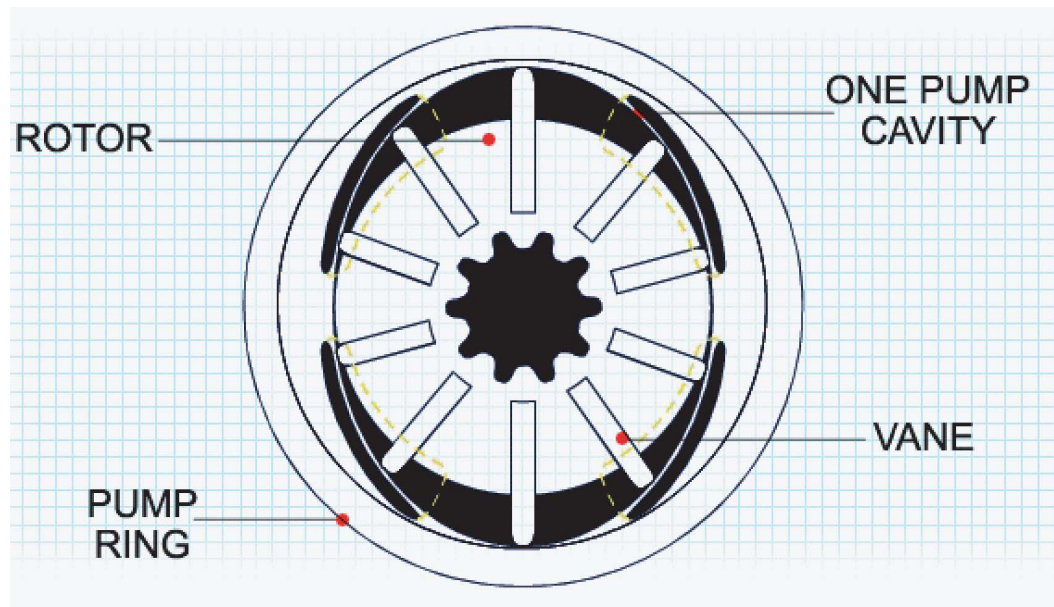


Figure 4-15, Rotor

The key to the operation of the pump is the elliptical design of the pump itself. As you can see, there are cavities located between the vanes. The vanes that are closed to the pump ring have very small cavities, while the vanes that are away from the ring have very large cavities.

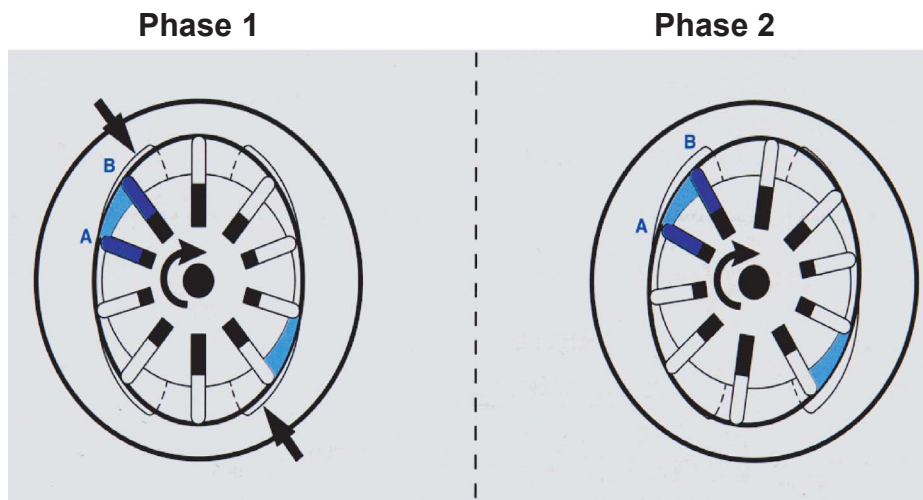


Figure 4-16, Pump Operation

In Phase 1, the rotor moves past the opposed suction ports, and the vanes move out to maintain contact with the ring. This creates a low-pressure area, drawing fluid into the cavities formed by the vanes.

As the rotor continues to move during Phase 2, the vanes follow the contour of the ring. The contour of the ring forms a larger cavity between the vanes. This increases the suction and draws in more fluid into the pump.

At Phase 3, the vanes are at the end of the intake port of the pump and the cavity has reached its maximum volume. In Phase 4, the rotor moves into alignment with the opposed discharge ports.

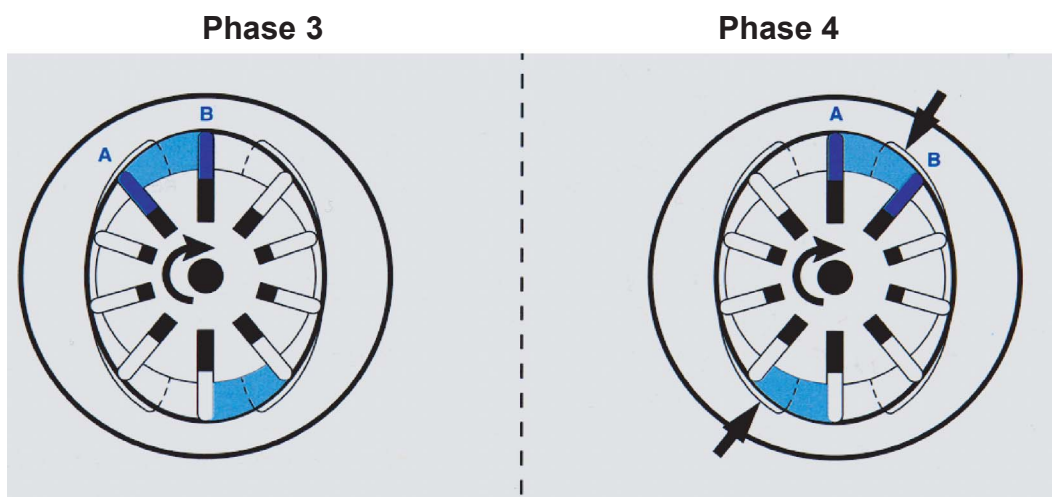


Figure 4-17, Vanes

The contour of the ring causes the vanes to move in towards the rotor. This reduces the volume of the cavity and creates a high-pressure area. The high will push the fluid out the discharge ports and into the power steering system.

As the rotor continues to move during Phase 5, the volume of the cavity decreases, therefore increasing the discharge pressure. At Phase 6, the last phase, the contour of the ring results in the minimum cavity volume, and the discharge of fluid is completed.

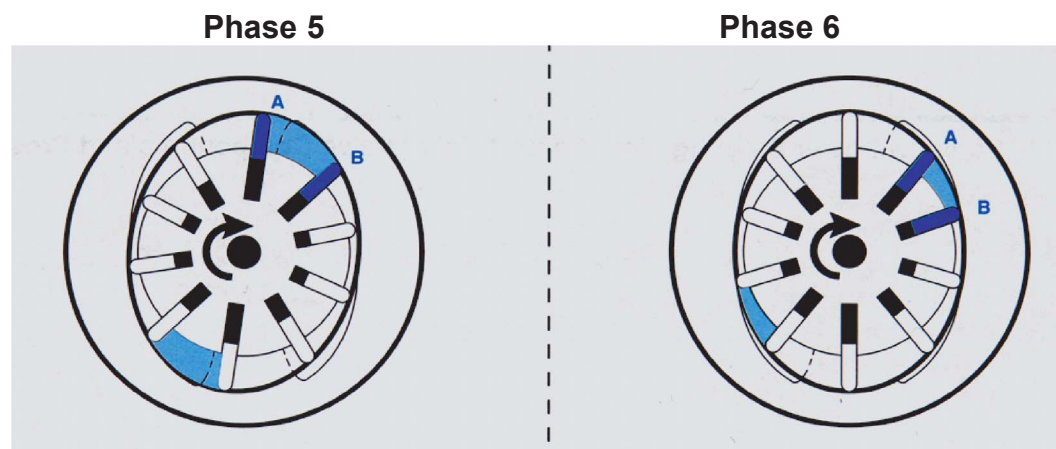


Figure 4-18,

As the rotor continues to move during Phase 5, the volume of the cavity decreases, therefore increasing the discharge pressure. At Phase 6, the last phase, the contour of the ring results in the minimum cavity volume, and the discharge of fluid is completed.



## Pump Flow Control/Relief Valve

All power steering pumps have a flow control/relief valve that controls the output of the pump.

The pump itself provides constant displacement during each revolution of the rotor. The flow output per minute from the pump is based on the speed of the rotor. The speed of the rotor is controlled by the speed of the engine.

Since this output can be excessive when the rotor speed is high, the pump is designed with a flow control/relief valve to control the fluid flow from the pump.

The valve maintains a constant flow rate, regardless of rotor speed, to prevent excessive pressure and heat in the power steering system.

The valve also releases excessive pressure in the system.

The main components of the flow control/relief valve are:

- The flow control spring
- The flow control valve
- The flow control orifice
- The pressure relief valve and spring

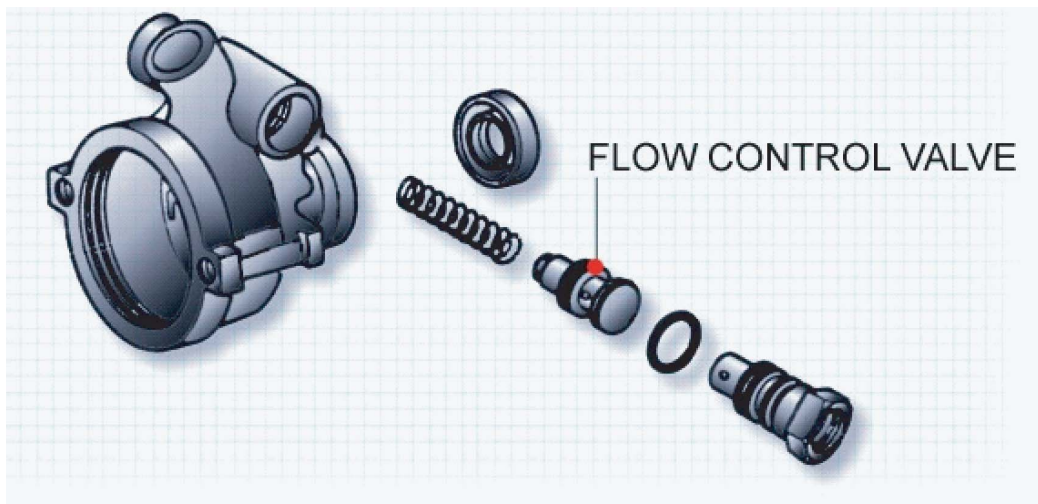


Figure 4-19, Pump Flow Control/Relief Valve

When the power steering pump begins operation, the fluid from the output of the pump flows into the control valve.

The fluid then flows through the orifice where a pressure differential is formed. The pressure differential results in a higher pressure on the pump side than on the system side.

The fluid from the orifice flows into the power steering system and through a passage on the backside of the control valve.

The fluid on the backside of the control valve is used to assist the spring force acting on the valve.

At this point, the combination of the spring force and hydraulic pressure is higher than the output pressure of the pump. This causes the control valve to block the passage to the pump intake.

When the output pressure is higher than the spring force and the pressure behind the valve, the control valve moves.

The movement of the valve opens the passage to the intake side of the pump. This allows some of the fluid to flow into the passage

As the pump speed continues to increase, the valve moves more to compensate for the higher pressure and flow.

The pressure and flow in the power steering system must remain in the correct range or the steering system components can be damaged. Failure of the control valve to regulate the pressure in the power steering system can result in excessive pressure and temperature.

As long as fluid can flow through the system, the control valve can regulate the pressure

However, there are times during normal operation when the flow in the system will stop.

Fluid flow can stop during parking maneuvers and when the steering wheel is turned to the extreme right and left positions.

When the fluid flow through the system stops, the pressure equalizes on both sides of the orifice. This creates equal pressure on both sides of the control valve

Since the back side of the valve has a spring, the combination of the hydraulic pressure and spring force positions the control valve to prevent flow into the pump intake passage.

As the pump continues to operate, the pressure in the system builds. If the pressure is not relieved, the system can. To prevent this, the control valve has a check valve inside of it. At a specific pressure, the check valve opens to relieve the pressure on the back side of the control valve.

This creates a pressure differential and allows the control valve to move. With the control valve moved, the high pressure is allowed into the pump intake passage.

At this point, the check valve and control valve seat.

## Hydraulic Hoses

Since the power steering pump and the steering gear are not part of the same assembly, the system requires two hoses to connect these components.

The pressure hose is connected to the flow control/relief valve. It provides the pressurized fluid to the steering gear.

The second hose is the return hose. It returns the fluid from the steering gear to the pump.

Some vehicles will use a cooler in the return path to the pump. The cooler is used to reduce the temperature of the fluid before it enters the pump.

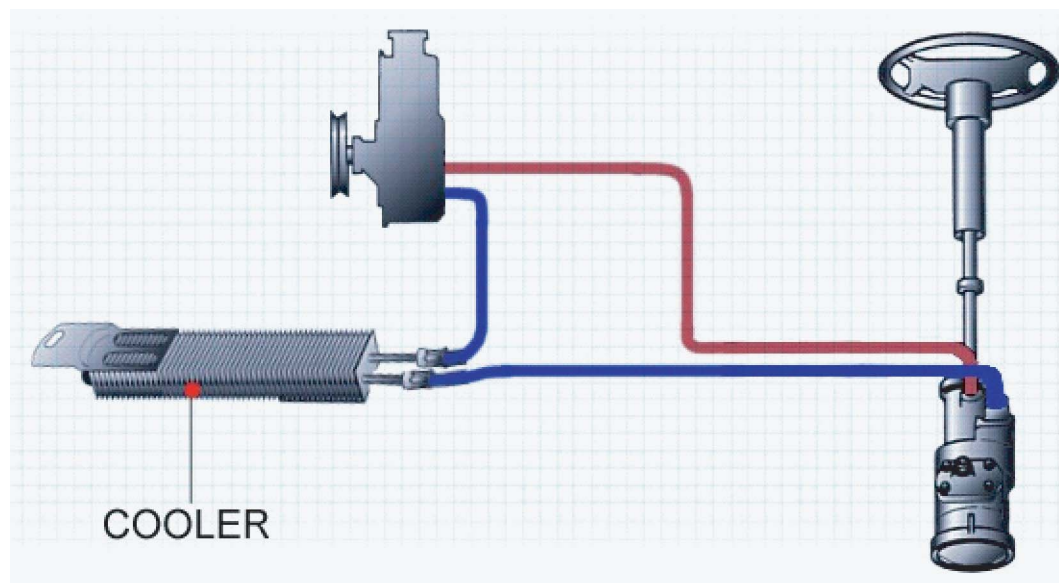


Figure 4-20, Hydraulic Hoses

## Hydraulic Assisted Steering

Now that we have discussed how hydraulic pressure is created in the power steering system, let's see how it assists in the operation of the steering gear.

We'll begin with the rack and pinion gearset.

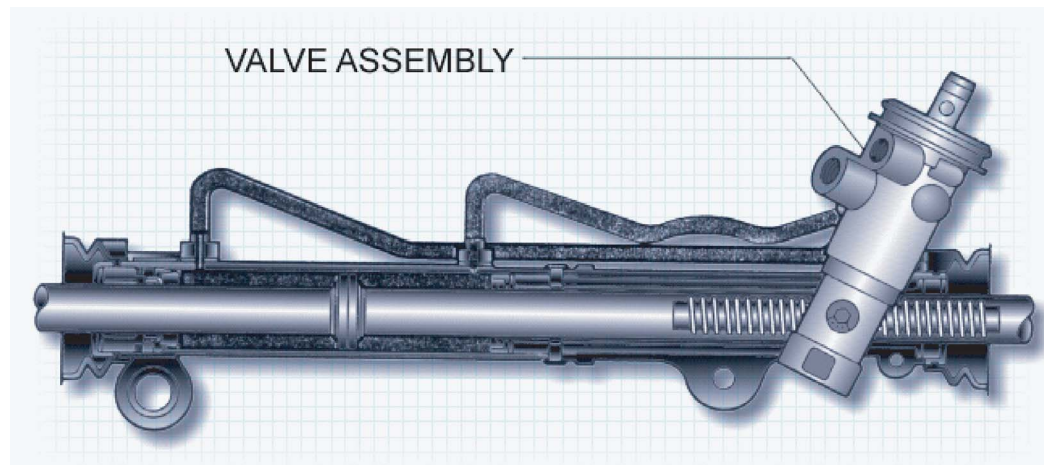


Figure 4-21,

During a turn, the pressurized fluid is directed to one side of the rack piston.

The fluid is directed to the left side of the rack piston during right turns, and is directed to the right side of the rack piston during left turns, depending on rack and piston location in relation to the wheels.

Now, let's look at the power assist steering integral gearset.

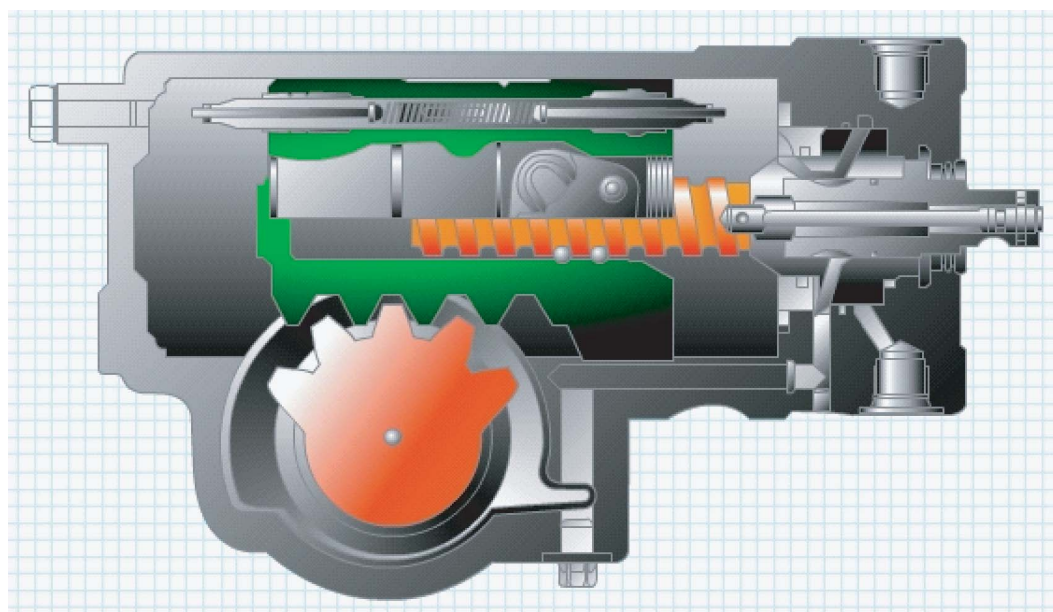


Figure 4-22,

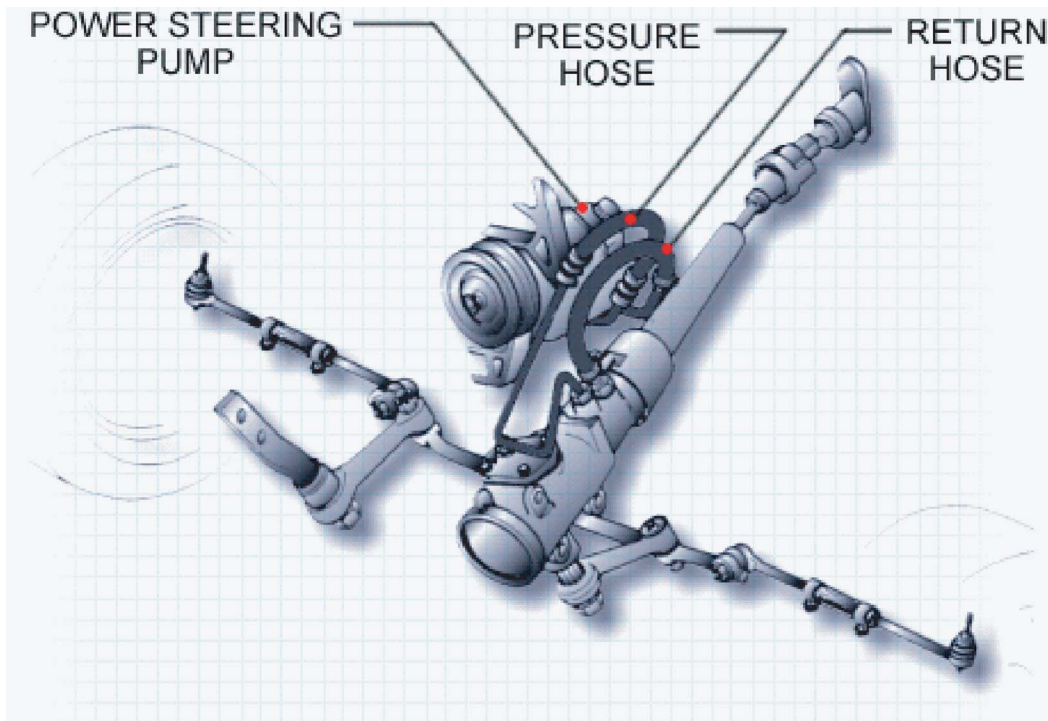
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Figure 4-23,

The pressurized fluid is directed to a cavity on one side of the rack piston. The rack piston in this gearset is similar to the ball nut in a manual steering integral gearset.

The rack piston moves up and down the wormshaft assisted by the power steering fluid pressure.

- The fluid is directed to the side of the rack piston closest to the steering wheel during right turns.

The pressurized fluid is directed to the back side away from the steering wheel during left turns.



## Steering Gear Valve Body Operation

The steering gear valve body is used to control the flow of hydraulic fluid into the steering gear. The valve body has three major components:

- Torsion bar
- Valve body
- Spool shaft

The valve body is pinned to the pinion gear of the steering gearset. The valve body rotates with the pinion gear. The valve body has passages that are designed to connect the hydraulic circuits and the steering gear body during different steering conditions.

The actual control of fluid flow is based on the spool shaft position. The spool shaft is splined to the intermediate steering shaft and it is also pinned to the torsion bar.

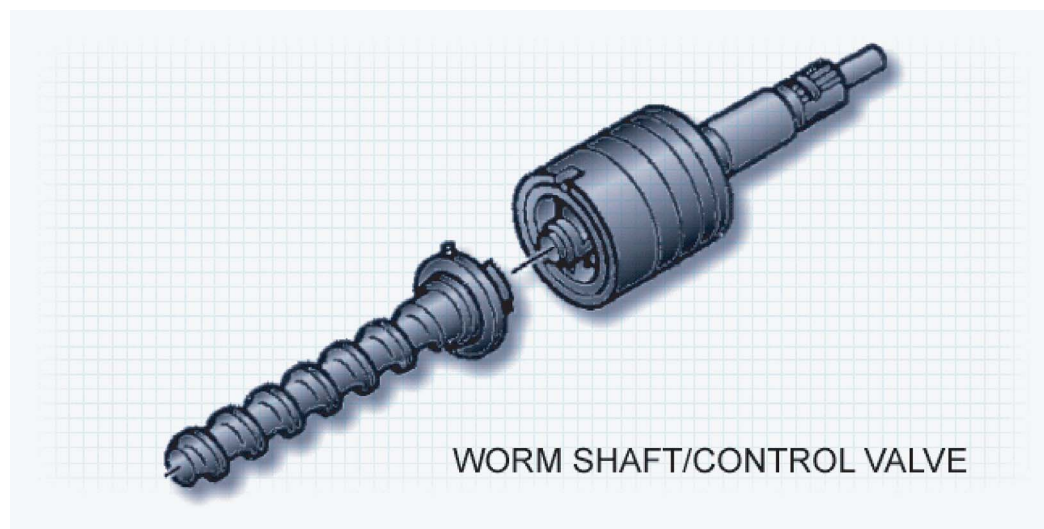


Figure 4-24,

The function of the torsion bar is to allow the rotation of the pinion gear to lag behind the rotation of the steering shaft. The torsion bar allows this by twisting based on the resistance of the pinion gear to the rotation and the torque applied to the steering shaft.

When the torsion bar twists, the spool valve moves out of alignment with the valve body. The slots in the spool. Now that we have looked at the function of the different components, let's look at the operation during the different steering conditions.

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When the steering wheel is not being turned, the valve body assembly is in the neutral position. In this position, the fluid from the pump flows from the steering gear body into a feed passage of the valve body then directs the fluid flow through the valve body.

When the steering wheel is rotated for a left turn, the pinion resists movement. This causes the torsion bar to twist. The twist in the torsion bar causes the spool shaft to rotate slightly ahead of the valve body and pinion.

The misalignment causes pressure to be directed to the right side of the rack piston. It also connects the left side of the rack piston to the return circuit.

The amount of fluid allowed to the right side is dependent on the amount of resistance at the wheels and the force exerted on the steering wheel.

When the steering wheel is rotated for a right turn, the resistance causes the torsion bar to twist. The twist in the torsion bar causes the spool shaft to rotate slightly ahead of the valve body and pinion.

The misalignment causes pressure to be directed to the left side of the rack piston. It also connects the right side of the rack piston to the return circuit.

The amount of fluid allowed to the left side is dependent on the amount of resistance at the wheels and the force exerted on the steering wheel.

## **Worm Shaft/Control Valve Operation**

Now, let's look at the integral gearsets.

The integral gearsets work in the same basic manner as the rack and pinion gearsets.

The integral gearsets use a worm shaft/control valve assembly instead of a steering gear valve body. However, the operation is the same

The main components of the worm/shaft control valve are the torsion bar, the spool valve, the valve body, and the intermediate steering shaft.

For this discussion on the operation of the worm/shaft control valve, we will use the Saginaw 710 steering gear.

It is slightly different from the other integral gearsets, as it has two rack pistons.

When the steering wheel is not being turned, the valve provides pressurized fluid to both sides of the two rack pistons. This prevents movement of the Pitman shaft and Pitman arm.

When the steering wheel is rotated for a left turn, the worm gear initially resists movement and causes the torsion bar to twist.

This twist causes the spool shaft to rotate slightly ahead of the valve body and worm gear.

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This misalignment causes pressure to be directed to the left side of the upper rack piston and the right side of the lower rack piston.

At the same time, the right side of the upper rack piston and the left side of the lower rack piston are connected to the return circuit.

The movement of both rack pistons turns the sector gear, which then moves the pitman shaft and pitman arm for a left turn.

When the steering gear is rotated for a right turn, the worm gear resists movement and causes the torsion bar to twist. As before, this twist causes the spool shaft to rotate ahead of the valve body and worm gear.

In this case, the misalignment causes pressure to be directed to the right side of the upper rack piston and the left side of the lower rack piston. The opposite sides of the rack pistons are ported to the return circuit.

The rack pistons now turn the sector gear which move the pitman shaft and pitman arm for a right turn.

Located in the steering gear is a pressure relief valve.

The purpose of this valve is to relieve hydraulic pressure when it exceeds 1550 psi.

The pressure relief valve connects the pressure circuit to the return circuit.

Whenever the relief valve is open, all hydraulic pressure is directed to the return circuit, and power-assisted steering is not available.

This brings us to the difference between the Saginaw 710 and the other Saginaw gearsets.

While the Saginaw 710 uses two rack pistons, all other gearsets use only one rack piston.

Other than this difference the components are essentially the same, and the basic operation remains the same.

The last integral gearset to be discussed is the TRW/Ross gearset.

This gearset is used on medium duty trucks. Its operation is virtually identical to the Saginaw gearsets. The only difference is the sector shaft is on the opposite side.

The operation of the valve in the Neutral position is the same as the Saginaw. The valve directs fluid to both sides of the rack piston.

This prevents movement of the Pitman shaft and Pitman arm so the front wheels do not turn.

When the steering wheel is rotated for a left turn, the worm gear resists movement and causes the torsion bar to twist.

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The twist in the torsion bar causes the spool shaft to rotate slightly ahead of the valve body and worm gear. The misalignment causes hydraulic pressure to be directed to the left side of the rack piston. The pressure on the right side of the rack piston is connected to the fluid return circuit.

Turning the steering wheel to the right repeats the same process as before with the worm gear, torsion bar and spool shaft. The only difference is the hydraulic pressure is directed to the right side of the rack piston, and the left side is ported to return.

## TRW/Ross Poppet Valves Operation

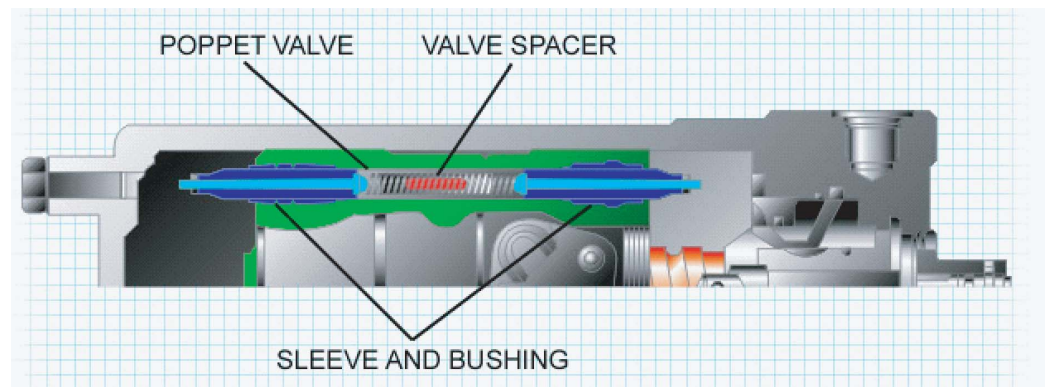


Figure 4-25, TRW/Ross Poppet Valve

The poppet valve in the TRW/Ross integral gearset is used to prevent hydraulic assisted steering within a 1/3 rotation of the steering wheel.

This prevents over-steering in a medium duty truck.

Turning the steering wheel left causes the poppet valve on the pressure side of the rack piston, the left side, to be unseated by hydraulic pressure.

The poppet valve on the other side, the right side, contacts a bolt inside the housing within a 1/3 rotation of the steering wheel.

- This connects the pressure and return lines to both sides of the rack piston.

This prevents power-assisted steering.

When the steering is turned right, the poppet valve on the right side of the rack piston is unseated by hydraulic pressure.

The poppet valve on the left side contacts a bolt within one-third rotation of the steering wheel.

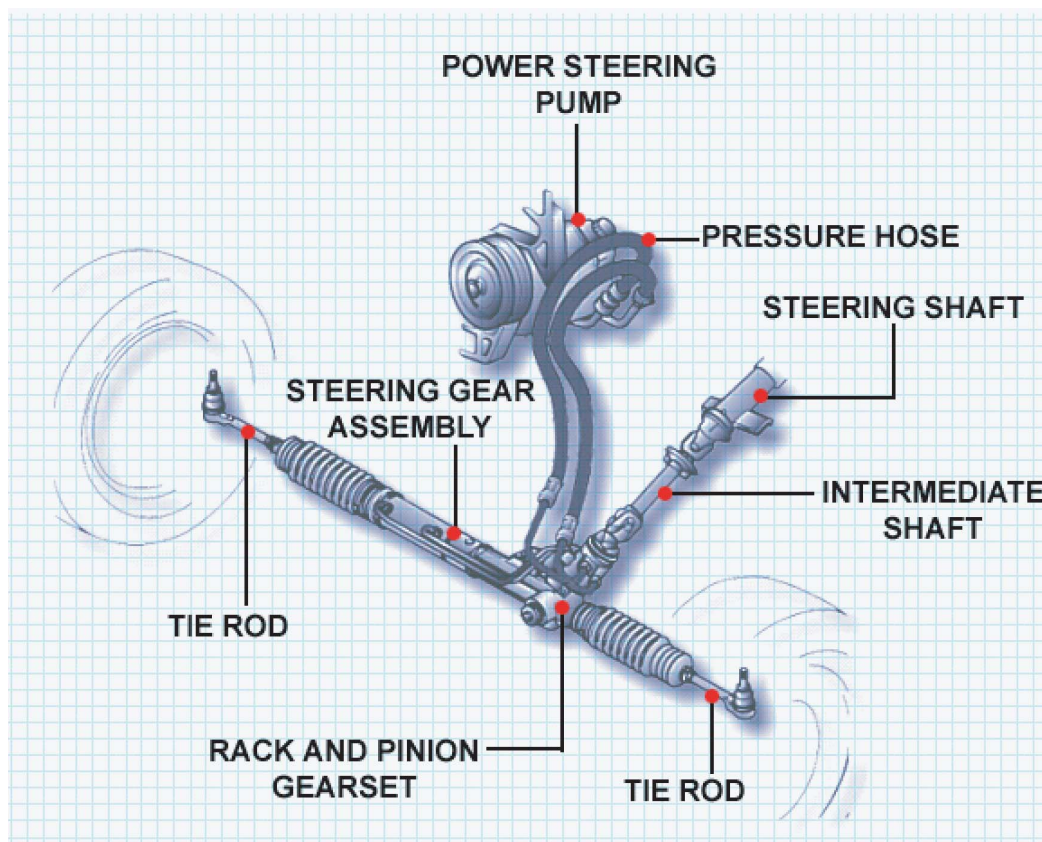
Both sides of the rack piston are connected to the pressure and return lines, and power-assisted steering is prevented.

This completes Lesson 2.

In this module, we reviewed the characteristics of basic hydraulic principles and the characteristics of the various components of the power-assisted steering system.

### Lesson 2 Test

1. A piston has 95 PSI of hydraulic force on the right side and 22 PSI of hydraulic force on the left side. There is a spring on the left side with 60 PSI of force. The piston will \_\_\_\_\_.
2. A hydraulic system has an orifice that is designed to provide a 50% pressure drop. The flow has stopped, but the pressure on the pump side of the orifice is 100 PSI. What is the pressure on the other side of the orifice?
3. The spring in the flow control/relief valve is broken, severely reducing its force. What will happen to the pressure created by the pump?
4. If the hydraulic force is prevented from acting on the right side (passenger side) of the rack piston, what will happen to the operation of the steering system?
5. Which side of the rack piston has pressure when the steering wheel is in the neutral position?





## Lesson 3. Variable Effort Steering System Operation

This lesson, Variable Effort Steering, will cover the operation of the variable effort steering systems. This lesson is divided into 7 sections and an end of lesson test.

### VES Variable Effort Steering

The VES systems are designed to provide variable power assisted steering. The amount of power assist increases at lower vehicle speeds for parking maneuvers and decreases at higher speeds for greater road feel.

General Motors uses four different VES systems:

- The Electronic Variable Orifice (EVO) system
- The Two-Flow Electronic (TFE) system
- The Speed Sensitive Steering (SSS) system
- The MAGNASTEER system

The Electronic Variable Orifice (EVO) system provides a wide range of power-assisted steering based on the vehicle's operating conditions.

The system uses vehicle speed and steering wheel speed to regulate the current to a solenoid that changes the orifice size of the flow control valve

The size of the orifice controls the flow rate through the valve and the pressure in the hydraulic system. The desired amount is then directed to the steering gear for the power assist.

The second type of power assist is the TFE system. As the name implies, it only provides two rates of power assist.

- At low speeds, the TFE solenoid provides maximum power assist.
- At high speeds, the solenoid provides minimum power assist.

The next type of power assist is the Speed Sensitive Steering (SSS) system. This system also provides a wide range of power assisted steering.

Unlike the EVO system, the SSS system uses hydraulic pressure to resist movement in the steering gear as speed increases. This provides a firmer sense of control and stability in the steering gear at higher speeds.

The fourth type of power assist steering used in General Motors vehicles is the MAGNASTEER system. The basic function of the MAGNASTEER system is similar to the SSS system.

The difference is how the system provides the resistance during the higher speeds. Instead of hydraulic pressure, the MAGNASTEER system uses an electromagnetic valve assembly to provide the resistance.

## VES System Inputs and Outputs

Each of the four different variable effort steering systems requires inputs and outputs in order to function properly.

The controller for the inputs and outputs may either be the Powertrain Control Module (PCM) or in a separate module.

The input for the controller for all VES systems is the vehicle's speed sensor.

Also, the EVO system contains a steering wheel speed sensor.

The main outputs from the controller for all four systems are:

- The EVO actuator
- The TFE solenoid
- The SSS valve/actuator
- The electromagnetic valve for the MAGNASTEER system

## Electronic Variable Orifice (EVO) System Components

The main components of the EVO system are:

- Vehicle speed sensor
- Power steering control module
- Steering wheel speed sensor
- Power steering gear, and the
- Power steering pump and solenoid actuator

We'll begin the explanation of the EVO system by looking at the cross-section of the EVO actuator.

We'll begin the explanation of the EVO system by looking at the cross-section of the EVO actuator.

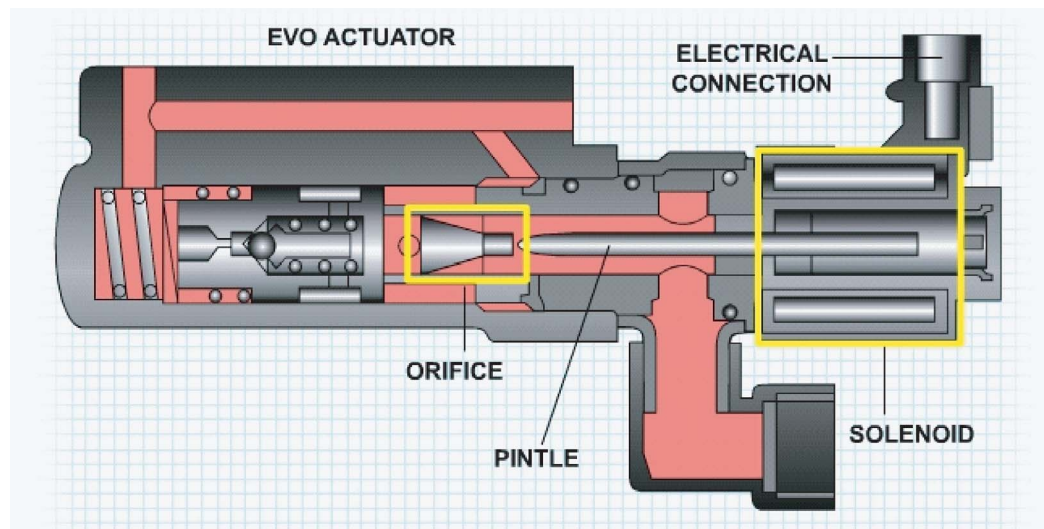


Figure 4-26, EVO Actuator

The actuator is a solenoid-operated pintle valve. Electrical current flow through the solenoid controls the position of the pintle in relation to the orifice.

As the vehicle speed increases, the control module provides a higher current flow and the solenoid positions the pintle to change the size of the orifice.

This increased speed results in a reduced amount of hydraulic flow and provides less hydraulic pressure to the steering gear.

The control module uses the signal from the vehicle speed sensor to calculate the required amperage for the solenoid.

The amperage has a direct affect on the steering effort and flow rate to the gear.

As the vehicle speed increases, the solenoid extends the pintle and reduces the size of the orifice. Hydraulic pressure is being reduced as the vehicle speed increases and less power assist is available.

The other sensor for the EVO system is the steering wheel speed sensor. This sensor is used to determine if the vehicle operator is performing an evasive steering maneuver.

In this situation, the controller increases the hydraulic pressure to assist the operator. The faster the driver turns the steering wheel, the stronger the signal generated by the sensor.

The faster the steering wheel is rotated, the more the solenoid retracts the pintle and enlarges the size of the orifice. This increases hydraulic pressure to the steering gear and provides more power assist for the operator.

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The next VES system is the Two-Flow Electronic (TFE) system. The main components of the TFE system are the:

- Power steering pump and solenoid actuator
- Steering rack and pinion gear
- Powertrain control module (PCM), and

**Multifunction Chime Module**

The TFE actuator is a solenoid-operated pintle valve.

The pintle valve only has two positions:

- Maximum assist, and Reduced assist

When the solenoid is provided a ground from the chime module, the pintle extends out from the orifice and provides maximum assist. When the chime module interrupts the ground path, the pintle moves in to restrict the orifice. This results in the reduced assist setting.

The PCM provides the chime module with a vehicle speed signal. The logic circuits in the chime module determine when to energize the solenoid. The solenoid is energized whenever the vehicle speed is approximately 20 mph or lower.

In this case, the pintle is extended out and the power steering pressure is high. This provides maximum assist and the steering effort is low. When the vehicle speed is higher than 20 mph, the pintle is moved in and the steering pressure is low. This provides reduced assist and higher steering effort.

**SSS System**

The third system is the Speed Sensitive Steering or SSS system. The major components of this system are:

- Power steering pump
- SSS actuator
- Steering gear, and the
- Road sensing suspension control module

The actuator is a solenoid-operated valve that controls the flow of fluid into the chambers of the steering gear valve.

As more fluid flows into the chamber, pressure is built against the four pistons that are located around the spool shaft. As the pistons are loaded and pushed against the spool shaft, steering effort is increased.



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Remember: Unlike the EVO and TFE systems, the SSS system uses hydraulic pressure to resist movement in the steering gear. The amount of fluid allowed into the chambers is based on the electrical current flow through the solenoid.

The Road Sensing Suspension (RSS) control module, using the signal from the vehicle speed sensor, calculates the required amperage for the solenoid.

The amperage has a direct affect on the steering effort and hydraulic flow rate into the chambers of the spool shaft.

As the vehicle's speed increases, more hydraulic pressure is built against the pistons and the steering effort is increased. The steering effort adjustment begins at a vehicle speed of 20 mph.

**Magnasteer**

The fourth type of VES steering system that General Motors uses is the MAGNASTEER system. This system uses a variable bi-directional magnetic rotary actuator built into the steering rack. The bi-directional magnetic rotary actuator has no effect on the hydraulic operation of the steering rack.

The main components in the system include:

- The power steering pump
- MAGNASTEER actuator assembly
- Steering gear
- Electronic Brake Control Module (EBCM)

The MAGNASTEER system uses a conventional rack and pinion steering gear and an engine-driven hydraulic pump to provide power assist

The MAGNASTEER actuator consists of the following:

- A permanent magnet attached to the rotary input shaft
- Pole-piece assembly attached to the pinion, and
- An electromagnetic coil mounted in the steering gear housing

Integrated with the pinion shaft is a spool valve that senses the level of torque in the shaft and applies hydraulic pressure to the steering rack whenever assistance is needed. The electromagnet acts in parallel with the input shaft from the steering wheel to open or close the spool valve.



The electromagnet generates variable torque, which can either increase or diminish the amount of steering torque that is needed to open the spool valve.

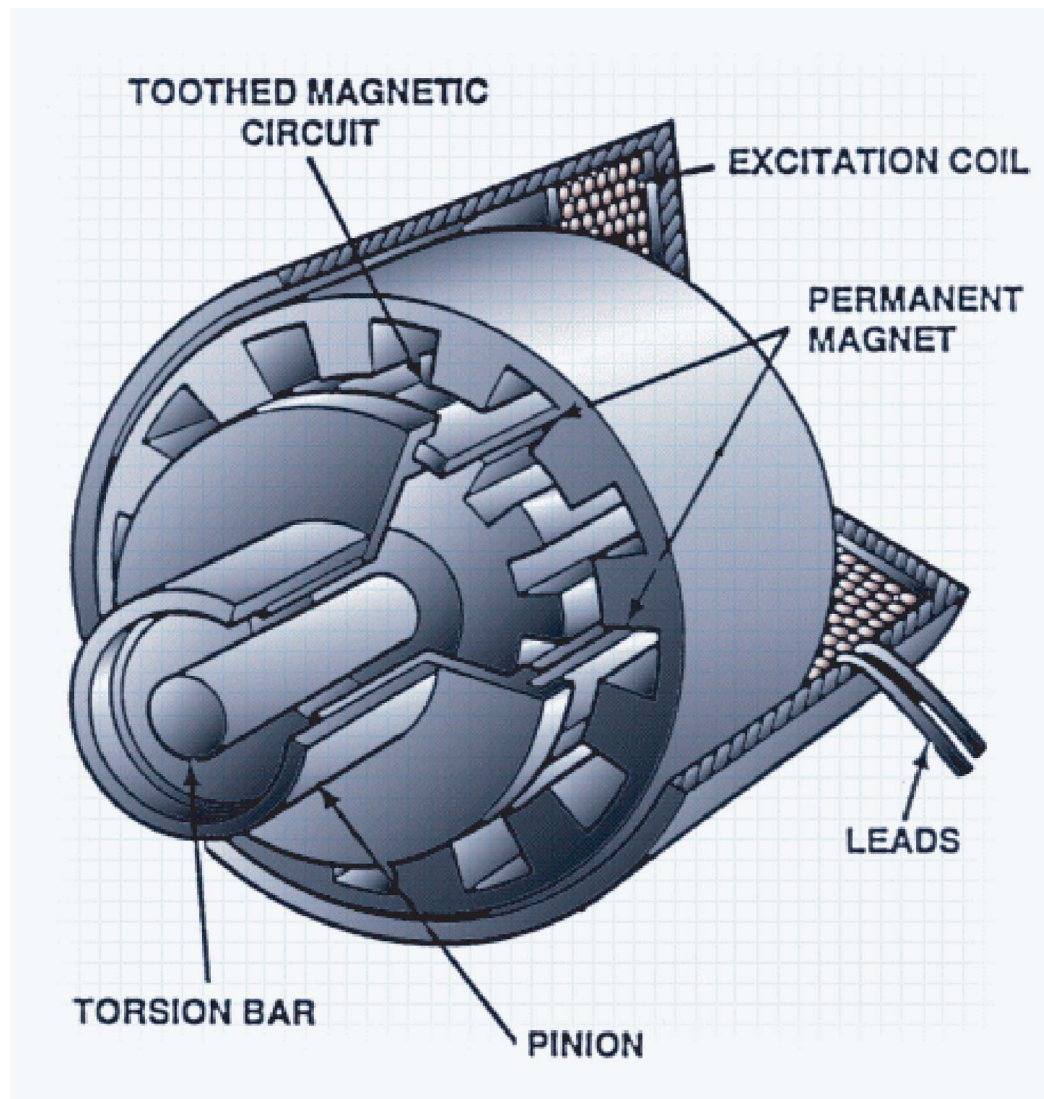


Figure 4-27,

To vary the amount of steering assist, the EBCM uses the signal from the wheel speed sensor to calculate the required amperage and direction of current flow to the MAGNASTEER actuator.

The amperage and direction of current flow has a direct effect on the steering effort and flow rate to the rack piston. When the vehicle is stationary, there is approximately 1.6 amps of current flow through the electromagnetic coil.

As the vehicle speed increases to approximately 45 mph, the current decreases to 0 amps. The EBCM then switches the direction of current flow.

Current flow through the electromagnetic coil causes either a magnetic attraction or repelling in the MAGNASTEER actuator.

At low vehicle speeds below 45 mph, the direction of current flow creates a magnetic field, which opposes the permanent magnet. The repelling force of the magnetic fields assists the spool valve in moving out of alignment with the valve body, and this increases the power assist.

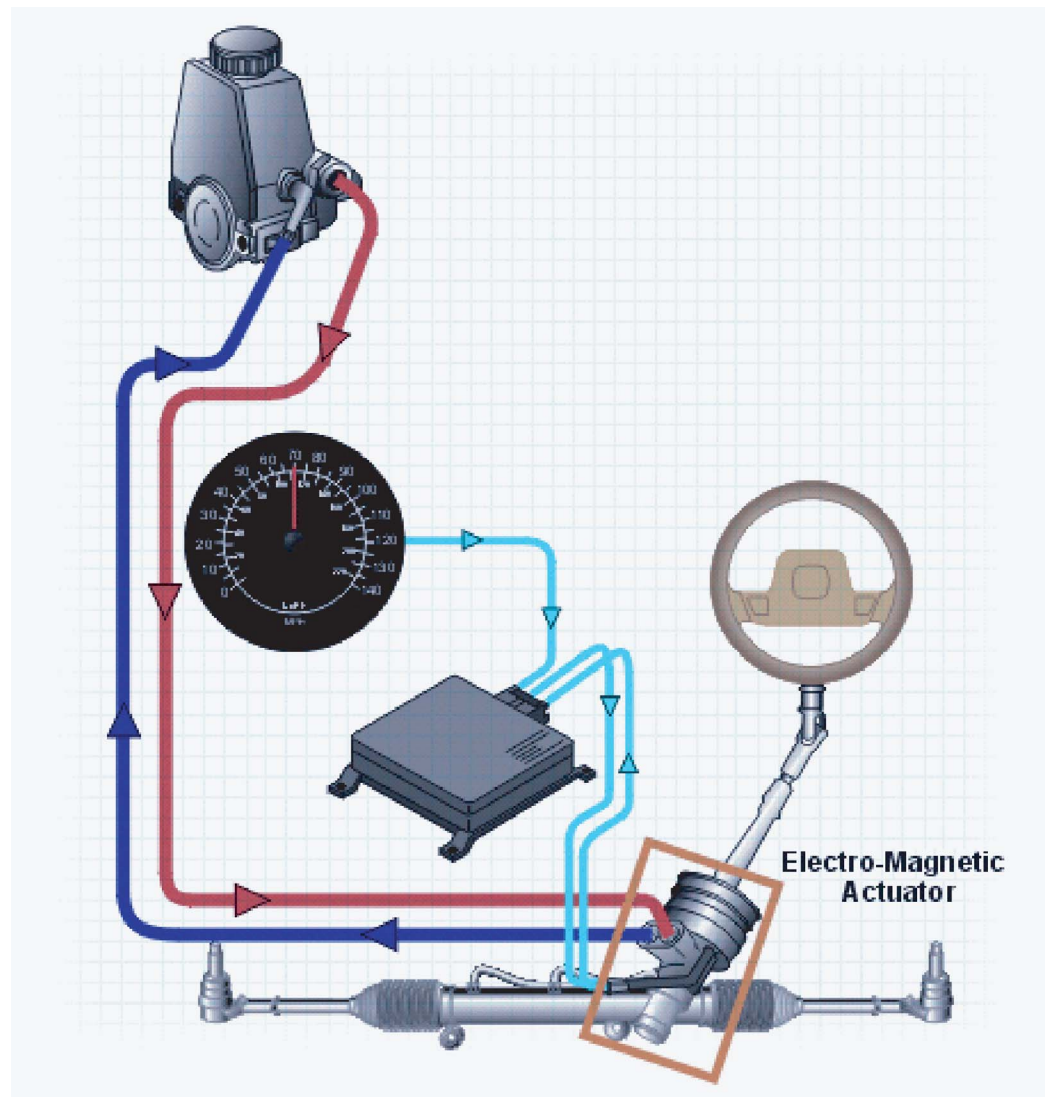


Figure 4-28,

With vehicle speeds below 45 mph, increased current provides increased steering assist. At vehicle speeds above 45 mph, the direction of current through the electromagnetic coil creates a magnetic field, which attracts the permanent magnet.

- The magnet helps keep the spool valve aligned with the valve body, and this reduces the power assist and provides a greater road feel.
- As the vehicle speed increases, the amount of effort required to overcome the attracting force of the magnetic fields increases.

With vehicle speeds above 45 mph, increased current flow provides decreased steering assist.

This completes Lesson 3.

In this Lesson, we reviewed the characteristics of the Variable Effort Steering Systems used in General Motor's vehicles

### Lesson 3 Test

1. Which of the Variable Effort Systems only provides two flow rates?
2. Which of the Variable Effort Systems uses hydraulic pressure to resist movement of the steering gear during higher vehicle speeds?
3. A controller malfunction results in high amperage to the EVO solenoid at all times. How does this affect steering effort operation?
4. Malfunction in the Speed Sensitive Steering system prevents hydraulic pressure to the four pistons. How does this affect steering system operation?
5. To vary the amount of steering assist, the EBCM uses the signal from the \_\_\_\_\_ to calculate the required amperage and direction of current flow to the MAGNASTEER actuator.
6. In the SSS system, hydraulic pressure is used to \_\_\_\_\_ movement of the steering gear.
7. An EVO system provides a wide range of power assist. As the vehicle speed increases, the amount of power assists \_\_\_\_\_.

## Steering Service Test

1. Which of the following can cause front wheel shimmy?
  - a. Improperly set camber
  - b. Wheel bearings set too tight
  - c. Loose steering linkage
  - d. Dragging brakes
  
2. Excessive steering wheel play is felt in the steering wheel on a manual steering system. Technician A says a worn Pitman arm could be the cause. Technician B says a misadjusted worm bearing may be the cause. Which technician is correct?
  - a. Technician A
  - b. Technician B
  - c. Both technicians are correct
  - d. Neither technician is correct
  
3. All of the following can affect the performance of a steering system EXCEPT \_\_\_\_\_.
  - a. the condition of the rear tires
  - b. the amount of weight on the front tires
  - c. the condition of the front suspension
  - d. a slipping transmission
  
4. Tightening the lash adjuster screw in a steering box \_\_\_\_\_.
  - a. reduces sector (Pitman) shaft end play
  - b. reduces steering shaft end play
  - c. reduces clearance between the sector and housing
  - d. increases steering effort

5. The steering column should never be supported by the lower bracket only. Damage may occur to the \_\_\_\_\_.
- a. lower bearing
  - b. upper bearing
  - c. SIR coil
  - d. BTSI
6. Which of the following steering gearsets is used in current GM passenger cars?
- a. Rack and pinion
  - b. Radial
  - c. Integral
  - d. Planetary
7. If power steering fluid is low and the proper power steering fluid is not available, which of the following may be substituted?
- a. Brake fluid
  - b. Hydraulic jack oil
  - c. Automatic transmission fluid
  - d. Substituting fluid is not recommended
8. Hydro boost power brake units use \_\_\_\_\_ for a source of power.
- a. engine vacuum
  - b. power steering pump
  - c. an auto transmission front pump
  - d. mechanical linkage

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9. A damaged worm shaft/control valve prevents the torsion bar from twisting when the steering wheel is turned clockwise. How does this prevent power assist during a right turn?
- a. Torsion bar twists in this direction; the spool valve allows pressurized fluid to the left side of the rack piston
  - b. Torsion bar can not twist in this direction; spool valve can only allow pressurized fluid to the right side of the rack piston
  - c. Torsion bar can not twist in this direction; the spool valve cannot allow pressurized fluid to the proper side of the piston
  - d. Torsion bar twists in this direction; the spool valve cannot allow pressurized fluid to the left side of the rack piston
10. If the worm gear bearings bind at times, which of the following could occur?
- a. Excessive steering effort/steering bind
  - b. Insufficient power assist at low vehicle speeds
  - c. No power assist
  - d. Power assist during right turn only
11. Technician A says that most rack and pinion vehicles have a sleeve that must be loosened in order to rotate a tie rod end and adjust toe. Technician B says that non-rack and pinion steering systems use a threaded tie rod and a locking nut for toe adjustment. Which technician is correct?
- a. Technician A
  - b. Technician B
  - c. Both technicians are correct
  - d. Neither technician is correct
12. A vehicle with rack-and-pinion steering has a shimmy. Technician A says that worn rack-to-frame mounting bushings could be the cause. Technician B says that loose inner or outer tie-rod ends (sockets) could be the cause. Which technician is correct?
- a. Technician A
  - b. Technician B
  - c. Both technicians are correct
  - d. Neither technician is correct



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13. Loss of power assist in one direction only can be caused by \_\_\_\_\_.  
a. low fluid level  
b. inoperative pump  
c. valve spool seals worn  
d. improper belt tension
14. Which of the following adjustments is required on a rack and pinion steering gear?  
a. Pinion bearing preload  
b. Pinion to rack clearance  
c. Rack bearing preload  
d. Rack gear end play
15. If the pinion gear teeth in a rack and pinion gear are damaged, which of the following should be done?  
a. Replace the rack and pinion assembly  
b. Some non-sequential gear damage is acceptable  
c. Replace the pinion gear teeth  
d. Replace the actuator
16. Which side of the rack has pressure when the steering wheel is in the neutral position?  
a. Right side  
b. Left side  
c. Both sides  
d. Neither side
17. Which of the following is a benefit of a rack and pinion gearset?  
a. It is compatible with front wheel drive vehicle design  
b. The Pitman arm provides additional turning leverage  
c. It is the only gearset that can be hydraulically assisted  
d. It improves steering sensitivity



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18. Which component of the rack and pinion steering system moves laterally to control the tie rods?
  - a. Pinion gear
  - b. Rack gear
  - c. Steering wheel
  - d. Pitman arm
  
19. A vehicle equipped with power rack and pinion steering has a rattle or chucking noise coming from the rack and pinion assembly. This could be caused by all of the following EXCEPT \_\_\_\_\_.
  - a. loose rack and pinion mounting bracket
  - b. low power steering pressure
  - c. loose tie rod
  - d. loose lower column bearing
  
20. A customer is concerned about an intermittent binding when turning. Technician A says that the problem could be a defective flex coupling. Technician B says that the problem could be a disconnected EVO solenoid. Which technician is correct?
  - a. Technician A
  - b. Technician B
  - c. Both technicians are correct
  - d. Neither technician is correct
  
21. Which of the following components of the integral gearset rotates to position the ball nut laterally?
  - a. Sector gear
  - b. Worm gear
  - c. Pitman gear
  - d. Pitman arm



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22. When is steering assist needed most?
- a. At highway speeds
  - b. Between 45-55 mph
  - c. When braking
  - d. While parking
23. A vehicle with power steering has no assist in either direction. Technician A says a low fluid level could be the cause. Technician B says a faulty flow control valve could be the cause. Which technician is correct?
- a. Technician A
  - b. Technician B
  - c. Both technicians are correct
  - d. Neither technician is correct
24. Which of the following correctly states when a power steering system should be bled?
- a. After fluid has been added to the system
  - b. Periodically according to the preventative maintenance schedule
  - c. After a high pressure hose is serviced
  - d. When the customer concern is noise related
25. Which of the following is NOT a possible cause for an increase in steering effort?
- a. Faulty power steering pump
  - b. Faulty steering gear
  - c. Damaged steering linkage components
  - d. Over inflated tires
26. If the hydraulic force is prevented from acting on the right side (passenger side) of the rack piston, which of the following will happen to the operation of the steering system?
- a. There will be power assist only during right turns
  - b. There will be power assist only during left turns
  - c. There will be no power assist
  - d. Power assist will not be affected

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27. While pressure testing a recirculating ball type power steering system, both left and right turning pressures are found to be low. Technician A says this is indication that the pump is bad and should be overhauled or replaced. Technician B says this is indication that the steering gear is bad and must be overhauled or replaced. Which technician is correct?
- a. Technician A
  - b. Technician B
  - c. Both technicians are correct
  - d. Neither technician is correct
28. The first step of bleeding a power steering system is accomplished by \_\_\_\_\_.
- a. opening a bleeder valve
  - b. removing the pressure line
  - c. removing the return line
  - d. turning the steering wheel
29. On a VES system, other than Magnasteer, varying the current flow through the control valve actuator varies the \_\_\_\_\_.
- a. hydraulic pressure
  - b. steering wheel rotation
  - c. fluid level
  - d. signal to the EBCM
30. A piston has 95 psi of hydraulic force on the right side and 22 psi of hydraulic force on the left side. There is a spring on the left side with 60 psi of force. This piston will.
- a. move to the right
  - b. move to the left
  - c. not move at all
  - d. move diagonally



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31. A hydraulic system has an orifice that is designed to provide a 50% pressure drop. The flow has stopped, but the pressure on the pump side of the orifice is 100 psi. What is the pressure on the other side of the orifice?
- 0 psi
  - 25 psi
  - 50 psi
  - 100 psi
32. If the output side of the pump does not have a restriction, it will \_\_\_\_\_.
- produce pressure
  - not produce pressure
  - have no volume
  - have minimum volume
33. Which of the following is the unit of measurement for flow in a hydraulic system?
- Gallons per minute
  - Pounds per square inch
  - Gallons
  - Pounds
34. Which of the following is the unit of measurement for pressure in a hydraulic system?
- Gallons per minute
  - Pounds/kilopascals per square inch
  - Pounds
  - Square inches
35. A leaking power steering pump return O-ring seal may cause all of the following EXCEPT \_\_\_\_\_.
- air ingestion
  - pump noise
  - external leaks
  - high pump pressure



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36. Technician A states that pump components (rotor valves, pump ring) should not be interchanged. Technician B states that interchanging pump components can affect the pressure output and durability of the pump. Which technician is correct?
- Technician A
  - Technician B
  - Both technicians are correct
  - Neither technician is correct
37. Which component of the power steering pump regulates the output of the pump at high speeds?
- Flow control/relief valve
  - Pump ring
  - Rotor
  - Pressure
38. The rotation of which of the following power steering pump components pressurizes the hydraulic fluid?
- Rotor
  - Thrust plate
  - Pump ring
  - Pressure plate
39. A power steering pump is growling when the wheels are turned. Which of the following is the most likely problem?
- Excessive pressure in hoses
  - Air in the fluid
  - Worn or damaged cam ring
  - Contaminated fluid



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40. A customer is concerned that the vehicle feels like it has no power steering when it is being parked. Technician A says this could be caused by low engine idle RPM. Technician B says a defective power steering pump could cause this. Which technician is correct?
- a. Technician A
  - b. Technician B
  - c. Both technicians are correct
  - d. Neither technician is correct
41. A vehicle has a noise coming from the power steering pump. Technician A says a loose pulley could be the cause. Technician B says air in the system could be the cause. Which technician is correct?
- a. Technician A
  - b. Technician B
  - c. Both technicians are correct
  - d. Neither technician is correct
42. Technician A says that flushing a power steering system is necessary whenever the fluid in the system is contaminated with water or solid particles. Technician B says the power steering system should be flushed whenever there is a pump failure. Which technician is correct?
- a. Technician A
  - b. Technician B
  - c. Both technicians are correct
  - d. Neither technician is correct
43. When turning a vehicle with power steering, the steering wheel surges or jerks regardless of the direction of the turn. Technician A says a sticking flow control valve could cause this. Technician B says this could be caused by low pump pressure. Which technician is correct?
- a. Technician A
  - b. Technician B
  - c. Both technicians are correct
  - d. Neither technician is correct



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44. Technician A says that the flow control valve provides regulated flow at high rpms. Technician B says that the flow control valve provides relief when the driver turns and holds the steering wheel. Which technician is correct?
- a. Technician A
  - b. Technician B
  - c. Both technicians are correct
  - d. Neither technician is correct
45. A faulty flow control valve may cause all of the following EXCEPT \_\_\_\_\_.
- a. reduced steering assist
  - b. overheating of pump system
  - c. low system pressure during turns
  - d. leaking fluid
46. The spring in the flow control/relief valve is broken, severely reducing its force. Which of the following will happen to the pressure created by the pump?
- a. It will be higher than normal
  - b. It will be lower than normal
  - c. There will be no effect on the pressure
  - d. The pressure will fluctuate from high to low
47. Technician A says that an improperly centered control valve can cause unequal steering assist or self-steering in a power steering system. Technician B says that internal fluid leaks in the steering gear assembly can cause unequal steering assist or self-steering in a power steering system. Which technician is correct?
- a. Technician A
  - b. Technician B
  - c. Both technicians are correct
  - d. Neither technician is correct

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48. A pressure test is being performed on a car with power steering. The pressure readings taken when the wheels are at the right and left stops are below specifications. The readings are normal when the tester shutoff valve is closed. Technician A says these readings could be caused by a bad steering gear. Technician B says these readings could be caused by a bad pump. Which technician is correct?
- a. Technician A
  - b. Technician B
  - c. Both technicians are correct
  - d. Neither technician is correct
49. In a right turn, the worm shaft will \_\_\_\_\_.
- a. turn in the same direction as the intermediate shaft
  - b. turn in the opposite direction as the vehicle
  - c. hold the ball nut in place
  - d. not turn
50. A vehicle has little or no power steering on right turns; left turns are normal. Which of the following could be the cause of this problem?
- a. Sticking flow control valve
  - b. Internal leakage
  - c. Sticking pressure regulator valve
  - d. Low fluid level
51. Which of the following inputs are used by all variable effort steering systems?
- a. Steering wheel speed sensor
  - b. Power steering pressure sensor
  - c. Vehicle speed sensor
  - d. Pump motor



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52. Which occurs in the Variable Effort Steering (VES) system, if the Power Steering Control Module (PSCM) does not control the valve actuator?
- a. The system defaults to full fluid restriction
  - b. Normal steering assist occurs
  - c. The system operates at maximum power assist
  - d. The service steering lamp illuminates
53. The steering wheel position sensor produces two signals. Which of the following signals does the Electronic Brake Control Module (EBCM) NOT use?
- a. Steering wheel direction
  - b. Steering wheel position
  - c. Steering wheel turning speed
  - d. Steering wheel tilt
54. Which of the following electronic steering control systems operates by restricting power steering fluid flow?
- a. Magnasteer
  - b. Electronic Variable Orifice
  - c. Electronic Pump Control
  - d. Vehicle Control Sensing
55. Which of the following best describes the EVO actuator circuit description?
- a. It receives increasing amperage that reverses polarity at 45 mph
  - b. It receives a PWM signal that increases with vehicle speed
  - c. It receives a PWM signal that is not affected by vehicle speed
  - d. It receives decreasing amperage that reverses polarity at 45 mph

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56. How much steering assist is provided when the steering assist control solenoid for an Electronic Variable Orifice (EVO) system does not receive a Pulse Width Modulated (PWM) signal?
- a. 1/3
  - b. Maximum
  - c. 1/2
  - d. Minimum
57. The steering wheel position signal allows the Electronic Variable Orifice (EVO)/Passlock module to recognize \_\_\_\_\_.
- a. abrupt or evasive acceleration
  - b. low Pulse Width Modulate (PWM) duty cycle at highway speeds
  - c. abrupt or evasive braking maneuvers
  - d. abrupt or evasive steering maneuvers
58. A vehicle with an EVO system has power assisted right turns but resists left turns. Which of the following could cause the concern?
- a. Damaged steering gear valve assembly
  - b. Clogged power steering pump inlet hose
  - c. Restricted pressure hose
  - d. Inoperative EVO actuator
59. A controller malfunction results in high amperage to the Electronic Variable Orifice (EVO) solenoid at all times. How does this affect steering system operation?
- a. It increases steering effort during low speed maneuvers
  - b. It provides excessive power assist at high vehicle speeds
  - c. Decreased steering effort during low speeds will not affect steering system operation
  - d. It will create high speed wander

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60. Which of the following variable effort steering systems provides two levels of power assist, as opposed to infinite variable assist?
- Magnasteer
  - Speed sensing steering
  - Two flow electronic
  - Electronic variable orifice
61. Variable effort steering systems \_\_\_\_\_.
- vary driver steering effort proportional to vehicle speed
  - vary driver steering effort proportional to engine speed
  - provide different steering effort for different drivers
  - provide different steering effort based on hydraulic fluid temperature
62. Which of the variable effort systems uses hydraulic pressure to resist movement of the steering gear during higher vehicle speeds?
- Magnasteer
  - Speed sensitive steering
  - Two flow electronic
  - Electronic variable orifice
63. Which of the following modules provides current to the Magnasteer actuator for operation?
- BCM (Body Control Module)
  - PCM (Powertrain Control Module)
  - EBCM (Electronic Brake Control Module)
  - IPC (Instrument Panel Cluster)
64. Which of the following variable effort steering systems uses an electro-magnetic power steering valve assembly?
- Electronic variable orifice system
  - Magnasteer system
  - Speed sensitive steering system
  - Two-flow electronic system



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65. Magnasteer actuators operate by \_\_\_\_\_.
- a. the PCM applying and releasing a ground circuit
  - b. a varying amperage that reverses polarity at 45 mph
  - c. the EBCM applying and releasing a ground circuit
  - d. the EBCM varying direction of hydraulic fluid
66. When energizing a brake transmission shift interlock solenoid, all of the following conditions must be met EXCEPT \_\_\_\_\_.
- a. ignition is on
  - b. transmission is in park
  - c. service brake is applied
  - d. parking brake is applied
67. The two types of brake transmission shift interlocks on GM vehicles are the \_\_\_\_\_ and the \_\_\_\_\_.
- a. bowl lock, interlock and solenoid
  - b. bowl lock, bypass valve
  - c. interlock and solenoid, bypass valve
  - d. bypass valve, lock-out device
68. The brake transmission shift interlock (BTSI) solenoid is engaged to prevent shift lever movement under all of the following conditions EXCEPT \_\_\_\_\_.
- a. ignition key in the on position
  - b. transmission in park
  - c. park brake not applied
  - d. turn signal is activated
69. During a collision, the \_\_\_\_\_ is designed to collapse.
- a. steering column
  - b. BTSI
  - c. mechanical anti-theft shield
  - d. SIR system



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70. After a collision, the technician should inspect all of the following steering column components EXCEPT the \_\_\_\_\_.
- a. sector shaft
  - b. steering shaft
  - c. steering jacket
  - d. shift tube
71. After a collision, a steering column is being inspected. Technician A says that the steering shaft should be replaced if the plastic injection points are protruding. Technician B says that the steering shaft should be replaced if the plastic injection points are missing. Which technician is correct?
- a. Technician A
  - b. Technician B
  - c. Both technicians are correct
  - d. Neither technician is correct
72. After a collision, a steering column is being inspected. It is found that the shift lever rotates independently of the tube. Technician A says that this is a normal operating characteristic. Technician B says that the shift tube should be replaced. Which technician is correct?
- a. Technician A
  - b. Technician B
  - c. Both technicians are correct
  - d. Neither technician is correct
73. After the replacement of a steering shaft, the SIR lamp illuminates. All of the following could cause this EXCEPT \_\_\_\_\_.
- a. damaged SIR coil during assembly
  - b. SIR system not enabled
  - c. SIR fuse not installed
  - d. steering column out of alignment



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74. Technician A says that to center the steering wheel, the wheel can be removed and rotate the wheel on the steering shaft. Technician B says that the length of the tie rods can be adjusted and reset the toe. Which technician is correct?
- a. Technician A
  - b. Technician B
  - c. Both technicians are correct
  - d. Neither technician is correct
75. To prevent the SIR coil from uncentering and becoming damaged during installation, the column must remain in the \_\_\_\_\_ position.
- a. off/lock
  - b. run
  - c. crank
  - d. accessory
76. When performing steering system service, it is important to prevent rotation of the steering shaft when disconnected from the steering gear. Rotation can cause damage to the SIR coil. The anti-rotation pin should be installed in the access hole at the \_\_\_\_\_ of the steering column.
- a. bottom
  - b. top
  - c. left side
  - d. right side
77. There is looseness in the steering column. Which of the following could cause this concern?
- a. Loose steering universal joints
  - b. Worn ball joints
  - c. Loose tie rod ends
  - d. Worn idler arm

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78. Which of the following can cause poor returnability in a manual steering system?
- Loose tie rod end
  - Binding ball joint
  - Excessive positive caster
  - Loose Pitman arm adjustment
79. After verifying a concern of stiffer than normal steering, the next step in the strategy based diagnostics would be to \_\_\_\_\_.
- make quick checks
  - perform a bulletin search
  - install a scan tool and check for DTCs
  - lube the front end
80. If a technician finds power steering fluid leaking from the rack and pinion boot, the technician should \_\_\_\_\_.
- replace the boot
  - replace the bulkhead seal
  - tighten the boot clamps
  - replace the gear assembly
81. Which of the following would you look for during a visual inspection of the steering system?
- Leaks around the steering system
  - Damaged Brake Transmission Shift Interlock (BTSI)
  - Product fix bulletins
  - Damaged sir coil
82. Most steering system concerns are diagnosed using \_\_\_\_\_.
- symptom tables
  - trial and error
  - diagnostic scenarios
  - fault isolation hierarchies



83. A power rack and piston steering system does not have power assist. The pump output has been checked and it is within specification. Which of the following would NOT cause a malfunction?

- a. Restricted pressure hose
- b. Damaged steering gear valve body assembly
- c. Leaking rack piston
- d. Loose tie rod

84. A rack and pinion gear set is malfunctioning under a load. Which of the following is the probable cause?

- a. Loose rack mounting bolts
- b. Worn tie rods
- c. Wrong steering fluid used
- d. Worn power steering belt

85. During a power steering test, a pressure reading of 700 psi with the special tool open \_\_\_\_\_.

- a. is within specification
- b. indicates a restriction
- c. indicates a clogged flow control valve
- d. indicates a flow control valve stuck open