SUBARU®

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CERTIFIED SUBARU TECHNICIAN®

Technicians Reference Booklet

Steering Systems Module

Module 502

AUTOMOTIVE Youth Educational Systems®

November 2004

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Technical Training

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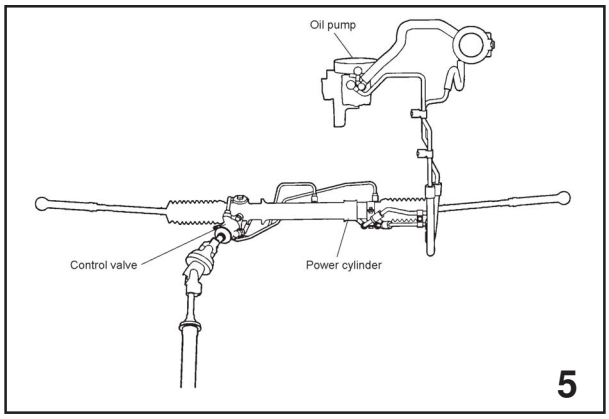
Introduction and Operation

Subaru Steering Systems utilize a rack and pinion steering mechanism. As the pinion gear rotates, the rack moves left or right. Rack and pinion steering gives the driver precise control over the wheels. The simple, compact design is easy to service.

Power Steering

A large force is required to operate the steering when a vehicle is stopped. As the vehicle speed increases, a smaller force is required to operate the steering. In other words, a very large force is required to operate the steering wheel when the steering wheel is turned while the vehicle is stopped. Power steering provides an extra force making it possible to steer the vehicle with the same force regardless of the vehicle speed.



Pump and Rack

Outline of the Steering System

The three main elements of the vehicle are driving, turning and stopping. Steering controls the element of turning.

Normally, vehicle are designed to drive straight ahead when the steering is not operated. When turning a corner or changing lanes, the direction of the tires must change and the vehicle must turn. Using a rack and pinion, the steering converts the force exerted by the driver on the steering wheel to a laterally directed force, and at the same time it boosts the force so that the vehicle can turn.

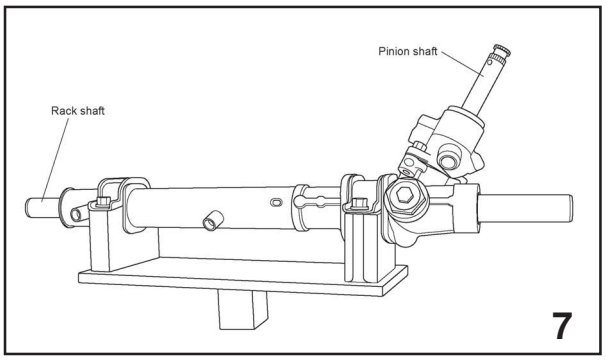
Overview

Pinion shaft

The function of the pinion shaft is to transmit the steering wheel turning force to the rack, causing it to operate.

Rack shaft

The rack shaft converts the rotational force of the pinion shaft to the lateral force, changing the direction of the wheel. It also functions to boost the steering force according to the ratio between steering wheel diameter and pinion diameter.

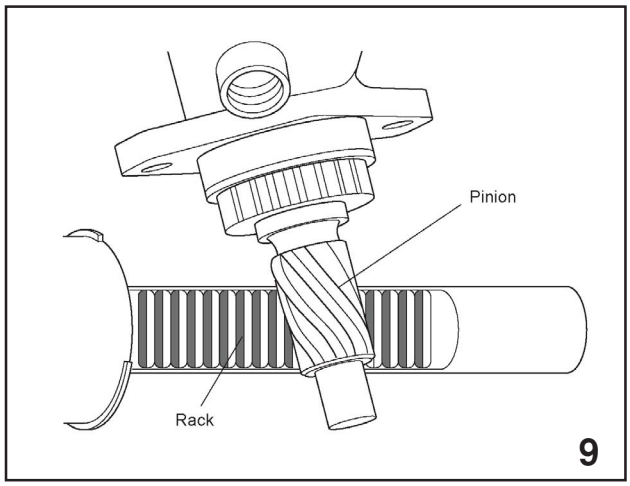


Rack mounted on holding tool

Steering Construction

Rack and Pinion

A rack-and-Pinion steering gear has a pinion installed on the end of the steering shaft. The pinion is meshed with a rack therefore the rotation of the pinion is converted to lateral movement of the rack, which moves the left and right wheels.



Pinion and Rack Gears

Steering Gear Ratio

NOTE: IN THE RACK-AND-PINION STEERING SYSTEM, THE GEAR RATIO CANNOT BE CALCULATED WITH THE RACK TREATED AS A STRAIGHT LINE (BECAUSE THE GEAR RATIO WOULD BE INFINITELY LARGE). ACCORDINGLY, THE STEERING ANGLE RATIO IS FROM THIS POINT FORWARD DESCRIBED AS THE GEAR RATIO.

THE STEERING GEAR RATIO INDICATES THE ANGLE OF THE TIRES WHEN THE STEERING WHEEL IS TURNED. FOR EXAMPLE, IF ONE ROTATION OF THE STEERING WHEEL (360°) CORRESPONDS TO A TIRE ANGLE OF 20°, THEN 360 ÷ 20 = 18,

THE NUMBER IN THIS EXAMPLE 18 REPRESENTS THE STEERING GEAR RATIO.

AS THE STEERING GEAR RATIO INCREASES, THE STEERING EFFORT DIMINISHES, AS DOES THE SHOCK IMPARTED TO THE STEERING WHEEL FROM THE WHEELS, BUT THE WHEEL RESPONSE DETERIORATES. AS THE STEERING GEAR RATIO DECREASES, CONVERSELY, THE STEERING EFFORT INCREASES, BUT THE WHEEL RESPONSE IMPROVES, POSSIBLY MAKING A HIGHLY SENSITIVE STEERING OPERATION.

Variable Gear Ratio (VGR) Power Steering

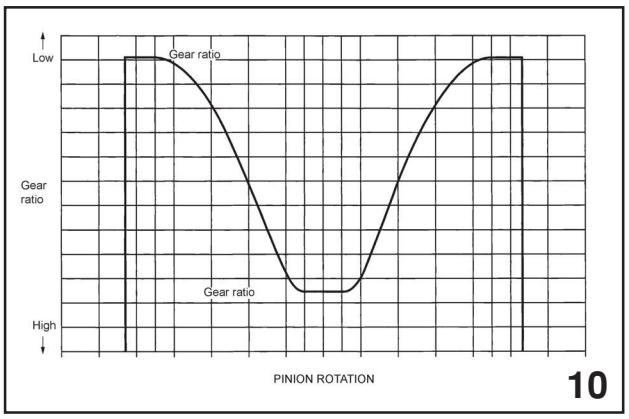
Certain vehicle models use a VGR type rack and pinion. With the VGR system, the gear ratio is varied depend on steering wheel turning angle.

While driving straight ahead:

A larger gear ratio is used to alleviate kickback and other adverse effects that occur while the vehicle is in motion. Road handling characteristics are also improved because the driver's body movements are not readily imparted to the steering.

While turning:

Steering response is improved because the gear ratio becomes smaller as the turning angle increases.



Pinion Rotation Chart

In the VGR system the angle of the gear equipped on the rack is varied, causing the pinion and gear contact point to vary. The gear is set on the rack so that the gear thickness increases as the gear moves away from the center of the rack. As the steering wheel is turned to the left or right, therefore, the gear ratio becomes correspondingly lower.

This means that the rack moving speed at both ends is larger than that of the center part.

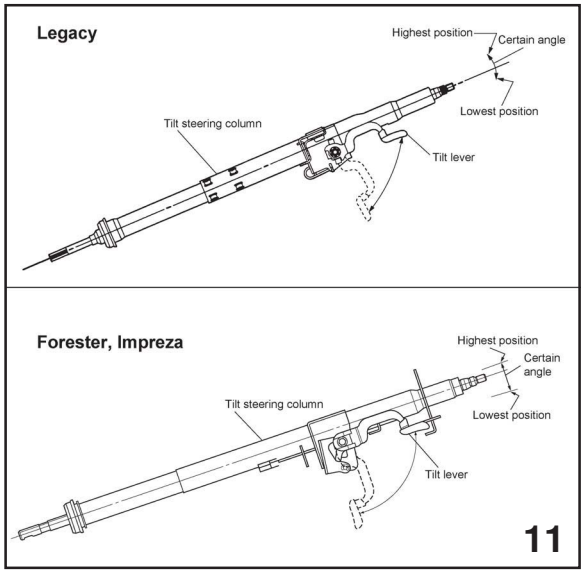
Accordingly, the gear ratio at both ends becomes smaller than that of the center part.

Steering Column

Tilt Steering

Tilt steering is an aid to safe driving, for it allows the driver to adjust the steering wheel position to suit his or her height and physique.

The steering wheel position is adjusted by moving the tilt lever downward, thereby releasing the steering wheel and allowing it to be raised or lowered within a certain range. The steering wheel can then be locked in position by operating the tilt lever again.



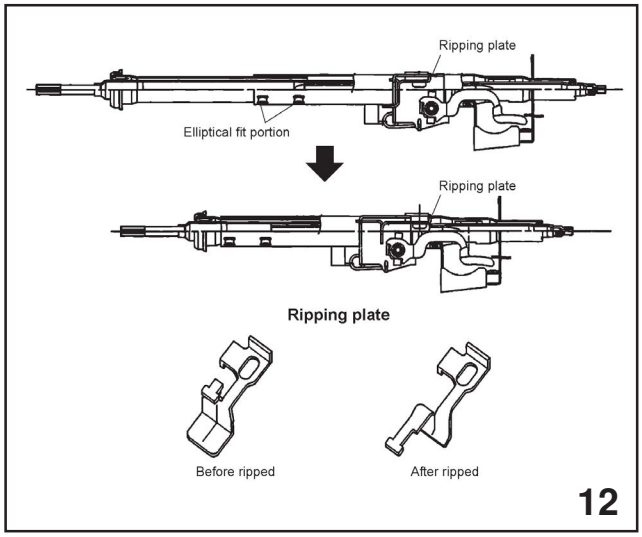
Steering Columns

Energy-absorbing Mechanism

An energy-absorbing mechanism is provided to protect the driver during a collision when his or her body comes into contact with the steering wheel because of inertia.

Ripping Plate System

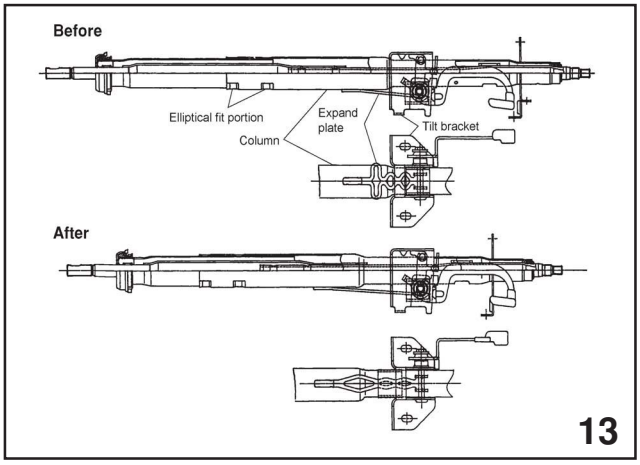
In the ripping plate system, the plate is set on a part of the tilt lever. When a collision occurs and the driver comes into contact with the steering wheel, the ripping plate breaks, causing the steering shaft to shorten, protecting the driver.



Ripping Plate System

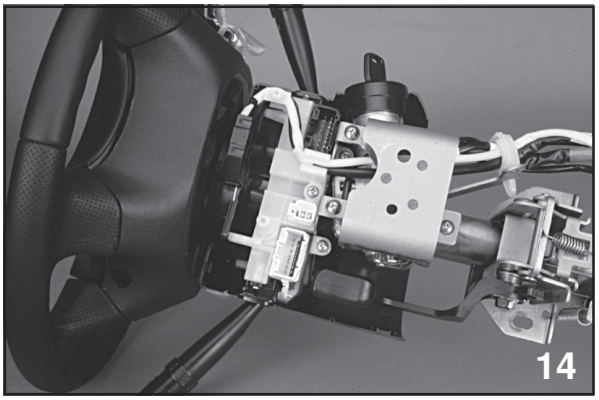
Expand Plate System

In the expand-plate system, the plate expands when the driver comes into contact with the steering wheel during a collision. This causes the steering shaft to shorten, protecting the driver.

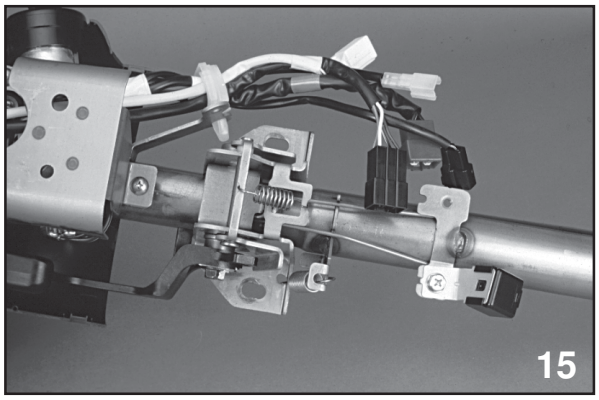


Expand Plate System

Impreza



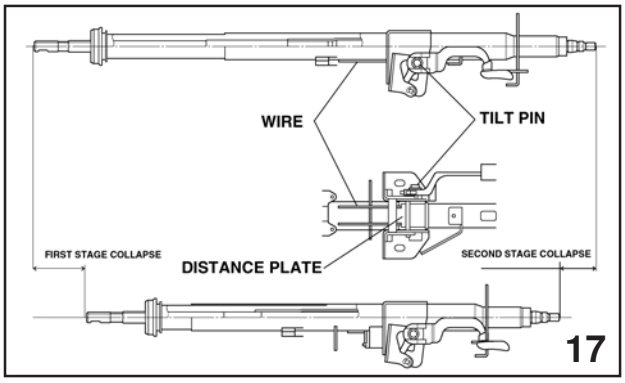
Impreza Steering Column



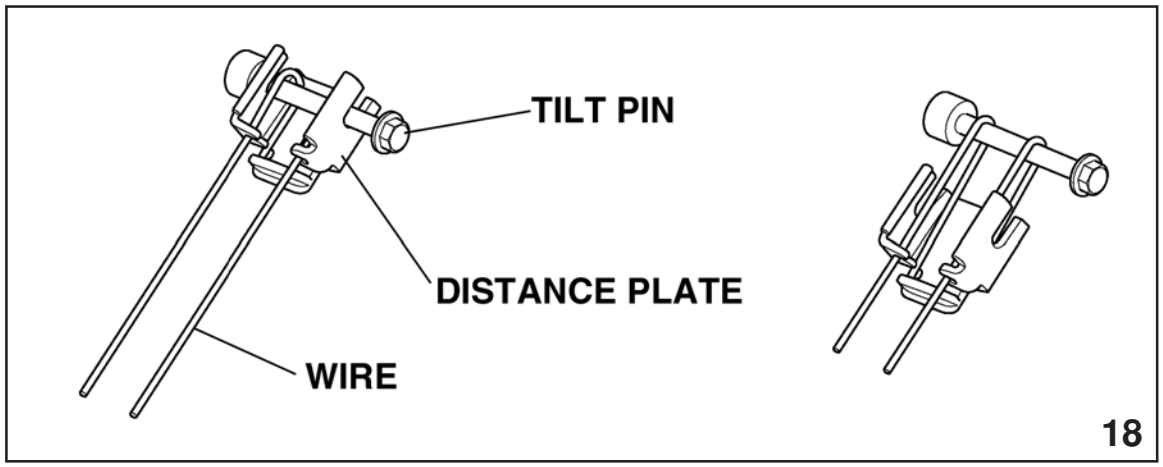
Energy absorbing wire

All 2002 and newer Impreza vehicles are equipped with a 2-stage energy absorbing steering column. The 2nd stage action is possible because of the use of an energy absorbing wire and mount. During the first stage collapse the lower section of the column slides into the outer section or jacket of the column. If a secondary force is applied to the upper part of the column, the energy absorbing wire will begin to stretch allowing the column and the steering wheel to move toward the dash.

Collapsible Steering Column



Before and after collapse



Energy absorbing wire operation

While this secondary collapse is occurring the column moves away from the mount and is supported only by the energy absorbing wire. The amount of secondary collapse will be in proportion to the energy contained in the secondary force.

Power Steering

Power Steering System Overview

The power steering is comprised of the oil pump, the control valve, and the power cylinder.

Oil Pump

Driven by the engine, the oil pump generates the oil pressure that operates the power cylinder, while the flow control valve built in the pump controls the oil flow rate.

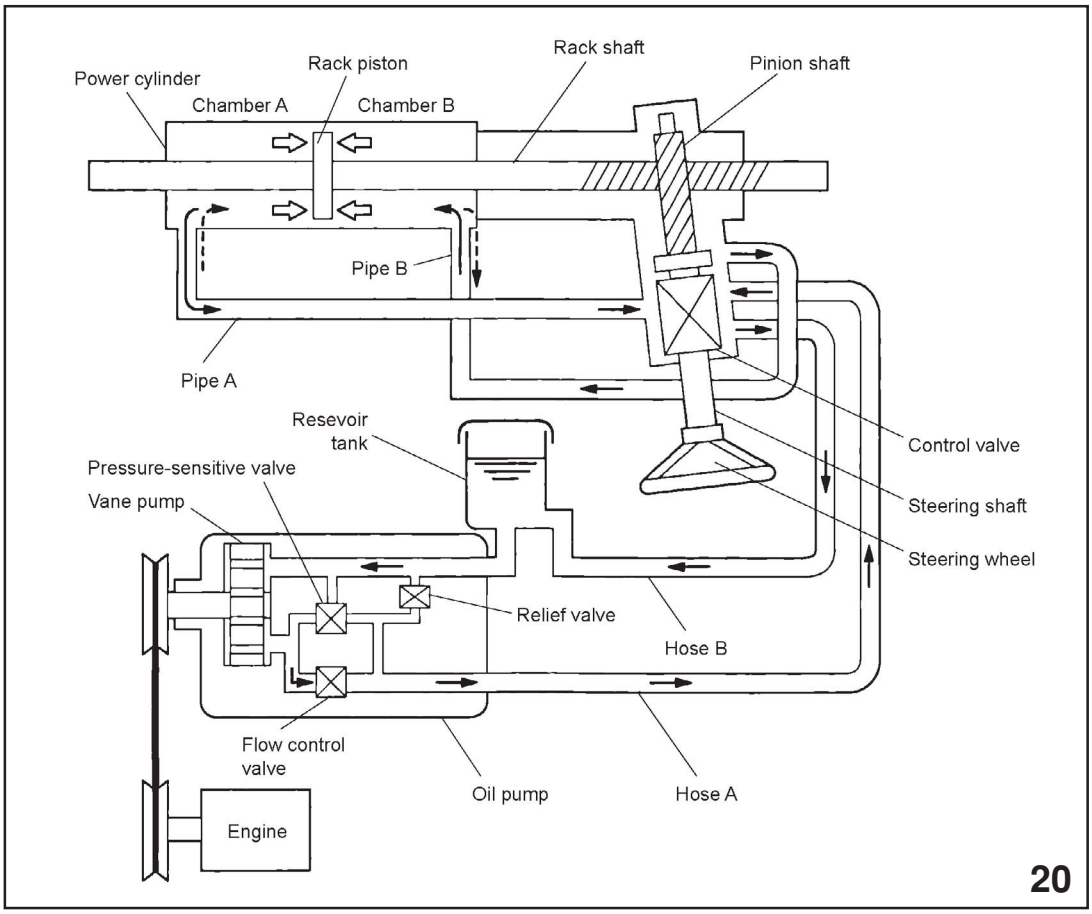
Control Valve

The control valve directs the oil to the left or right power cylinder.

Power Cylinder

The power cylinder is comprised of a piston installed on a rack shaft and cylinder, and it is operated by the oil pressurized by the oil pump.

The oil pressurized by the oil pump is fed through the flow control valve to the steering gearbox, and afterwards it is returned to the reservoir tank.

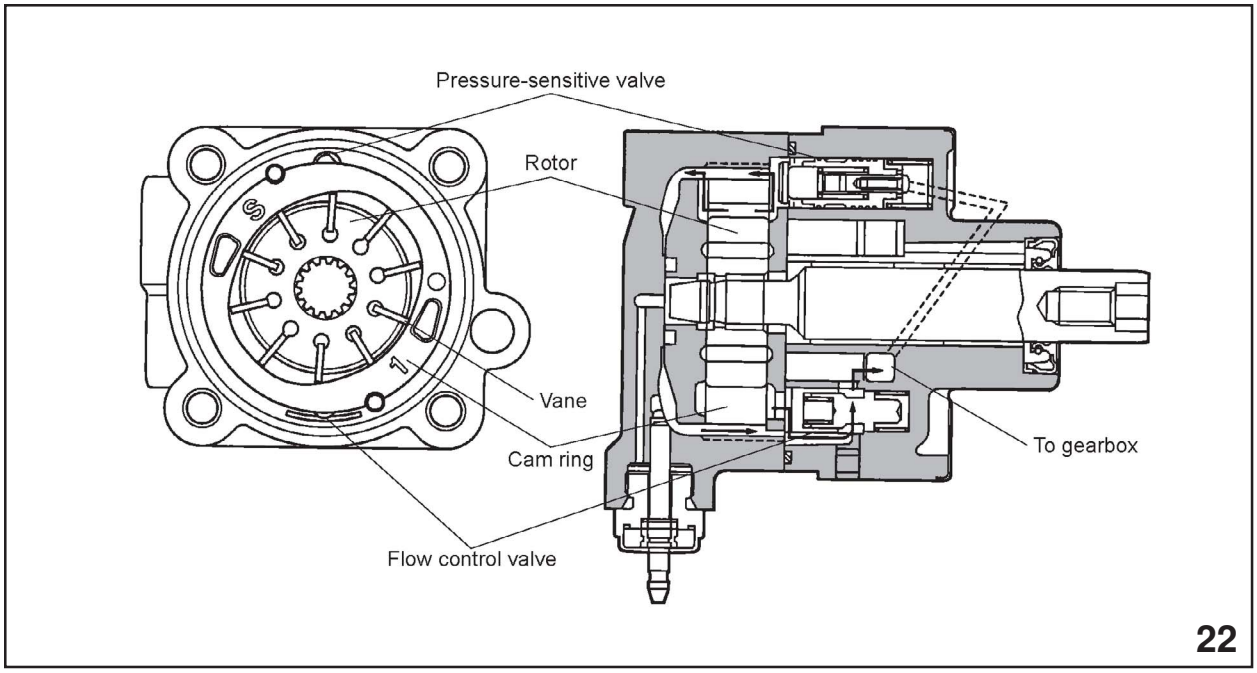


Hydraulic Layout

Oil Pump

The oil pump is driven by the engine by means of a belt. It is a vane-type pump comprised of a rotor, cam ring, and 10 vanes.

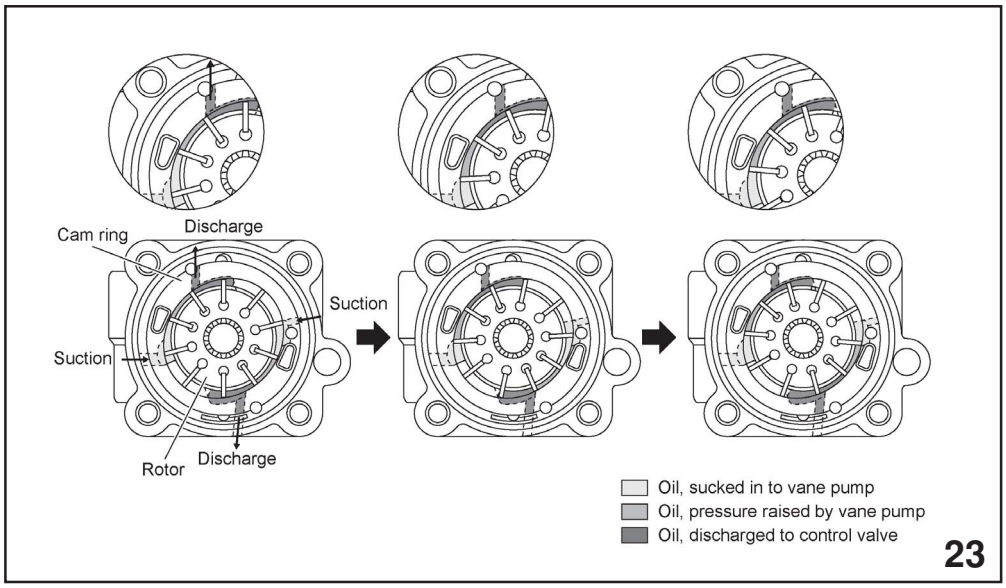
In addition, a flow control valve, pressure-sensitive valve, and relief valve are provided to control the oil pressure.



Power Steering Pump

Oil Pump Operation

When the oil pump rotor is turned by the engine, the vanes which fit into each groove of the rotor are pushed outward by the centrifugal force of the rotor and press against the cam ring. Because the cam ring is shaped oval to the rotor, a negative pressure is created in the pump suction port that draws in oil, and a pressurized oil is created on the discharge side that is forced out of the discharge port.

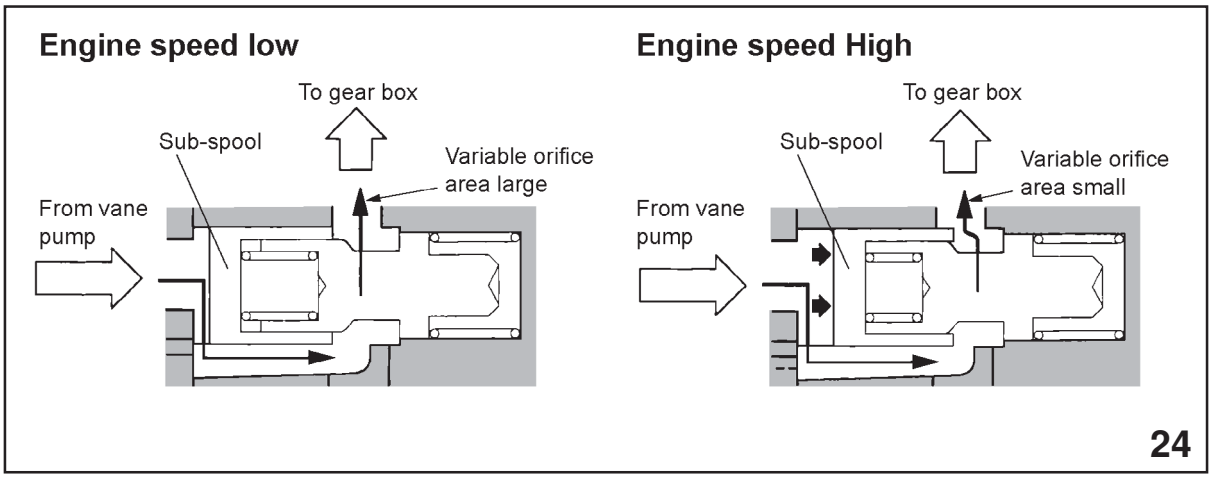


Power Steering Pump Operation

Flow Control Valve Operation

In order to obtain a small steering effort at low speeds and obtain a large steering effort at high speeds, this valve suitably controls the flow rate of working fluid to the gear box out of the pump discharge port which increases in proportion to the pump speed.

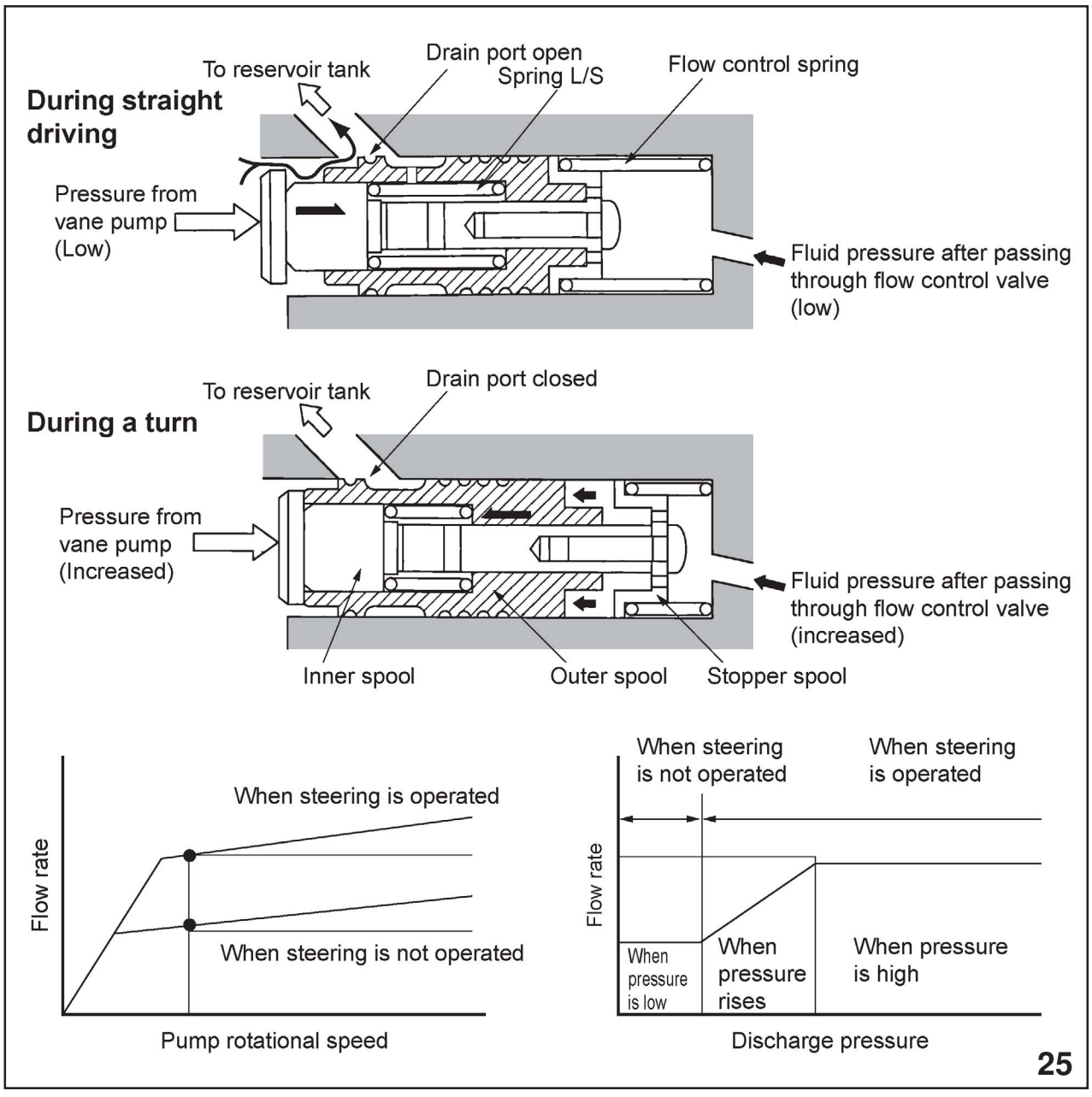
A sub spool is installed inside the flow control valve. When the oil pump discharge rate, overcomes the force of a spring in the sub spool, the sub spool moves to the right, reducing the width of the oil channel to the gearbox, controlling the oil flow rate.



Flow Control Valve Operation

Pressure-Sensitive Valve

This valve prevents energy loss by reducing the oil flow rate to the control valve and lowering the pressure losses in the system (piping, gearbox, and pump) when the steering is not operated (during low-pressure conditions).



Pressure-Sensitive Valve Operation

	Steering		Drain port	Oil flow rate	Pump power consumption
When pressure is low	When steering is not operated		Large	Low	Small
When pressure increases	When steering is not operated	Valve opearation starts	Medium	Medium	Medium
When pressure is high		Valve opearation ends	Small	High	Large

1. When pressure is low (steering is not operated)

When the steering is not operated, the oil pressurized by the oil pump simply passes through the control valve, so the oil pressure does not rise. At the same time, the drain port is widely opened because the pressure sensitive valve outer spool is pushed against the stopper spool by the spring L/S.

Since the flow control spring set load is low, this causes the oil pressure produced by the vane pump is drained away, reducing the pressure difference at the front and rear of the spool assembly and the discharge flow rate to the control valve.

2. When pressure increases

When the steering wheel is turned to the left or right, the control valve is also turned and passage to the reservoir tank is closed. Therefore, oil pump discharge pressure increases.

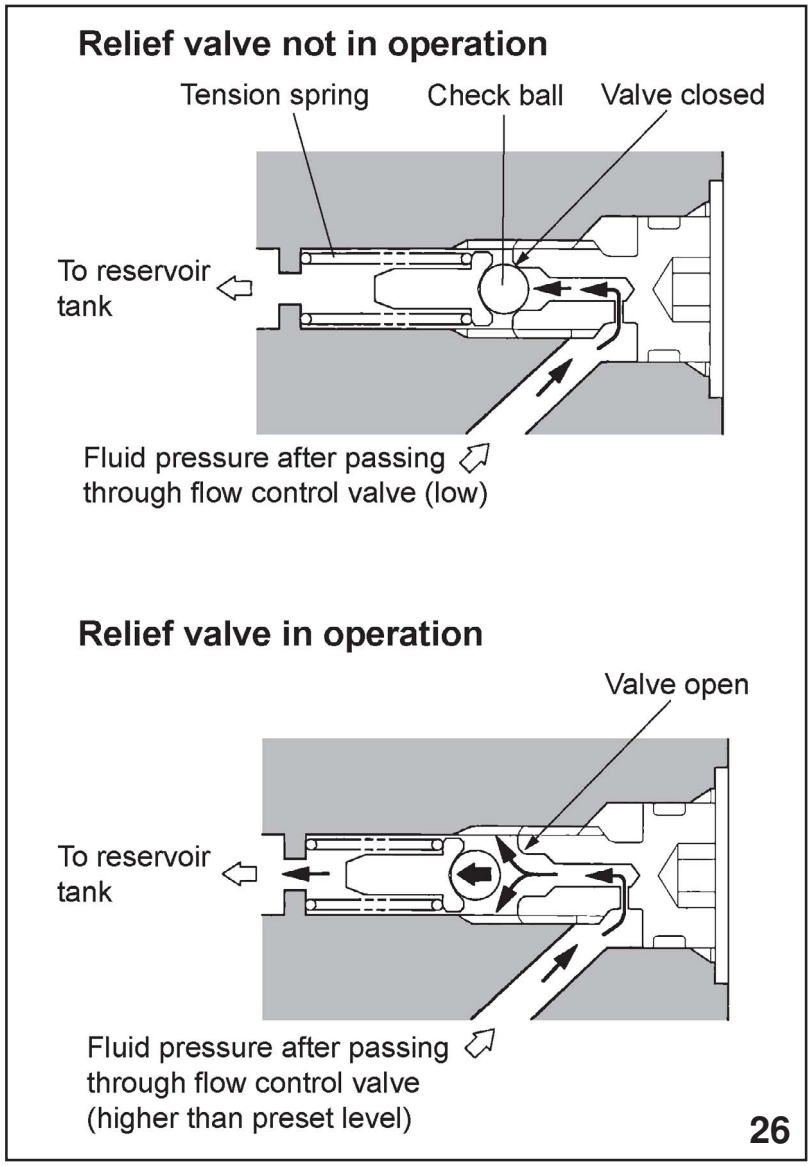
3. When pressure is high

At high pressure conditions the outer spool contacts the inner spool front end and the two parts work in unison, keeping the oil flow rate at maximum.

Relief Valve

The relief valve is comprised of a tension spring and check ball. Oil pressure from the flow control valve is applied to the right side of the relief valve, and the left side is connected to the oil reservoir tank.

During normal operation, the check ball inside the valve is pushed to the right side by the spring force, and the valve is closed. When the oil pressure from the flow control valve rises abnormally (when the steering wheel stays locked, for example), the oil pressure overcomes the spring force and moves the check ball to the left, opening the valve and allowing the oil pressure to escape into the reservoir tank preventing the pressure from being excessive. When the oil pressure from the flow control valve drops afterwards, the spring force closes the valve again.

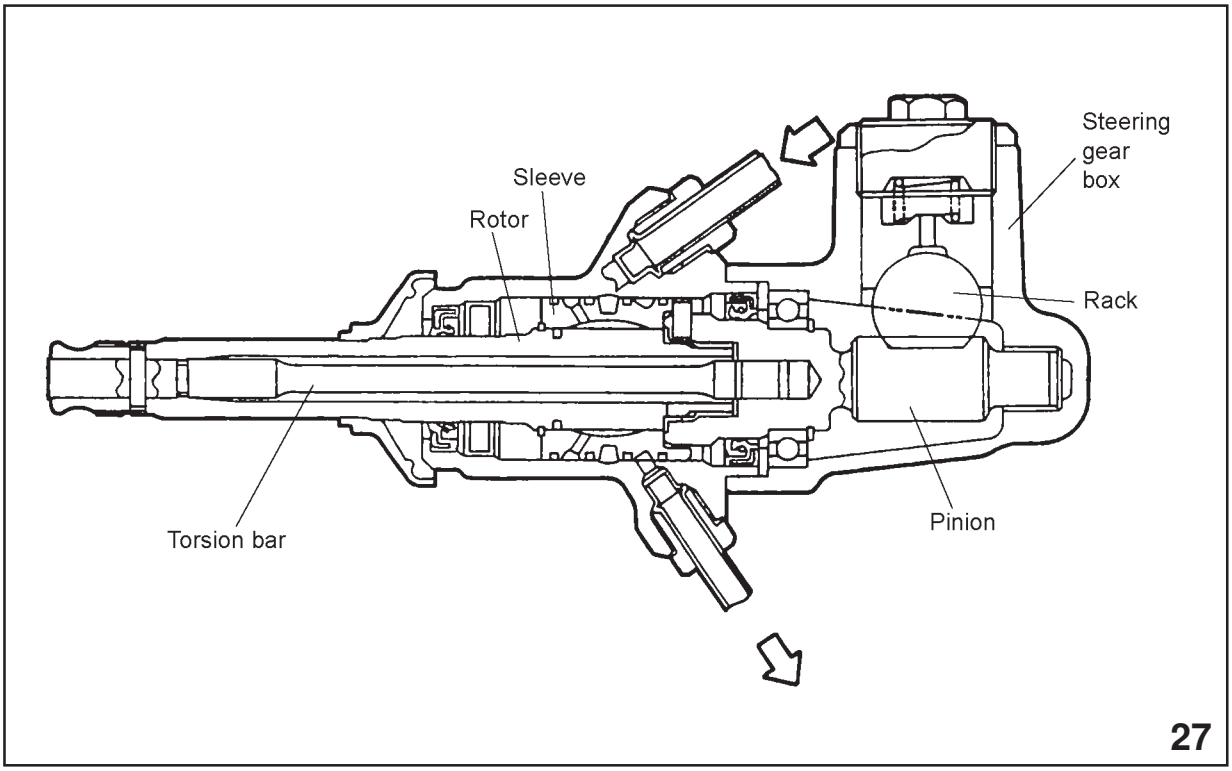


Relief Valve Operations

Control Valve

The control valve consists of a rotor, which rotates together with the steering shaft, and a pinion that rotates together with the sleeve and the torsion bar. The pinion and rotor are loosely engaged with a spline, and the torsion bar which is twisted by the turning force applied to the steering wheel connects them. This generates a relative displacement of the rotor and sleeve and thereby increases or decreases the oil channel cross-sectional area and controls both the change over of the working fluid channel and the working pressure.

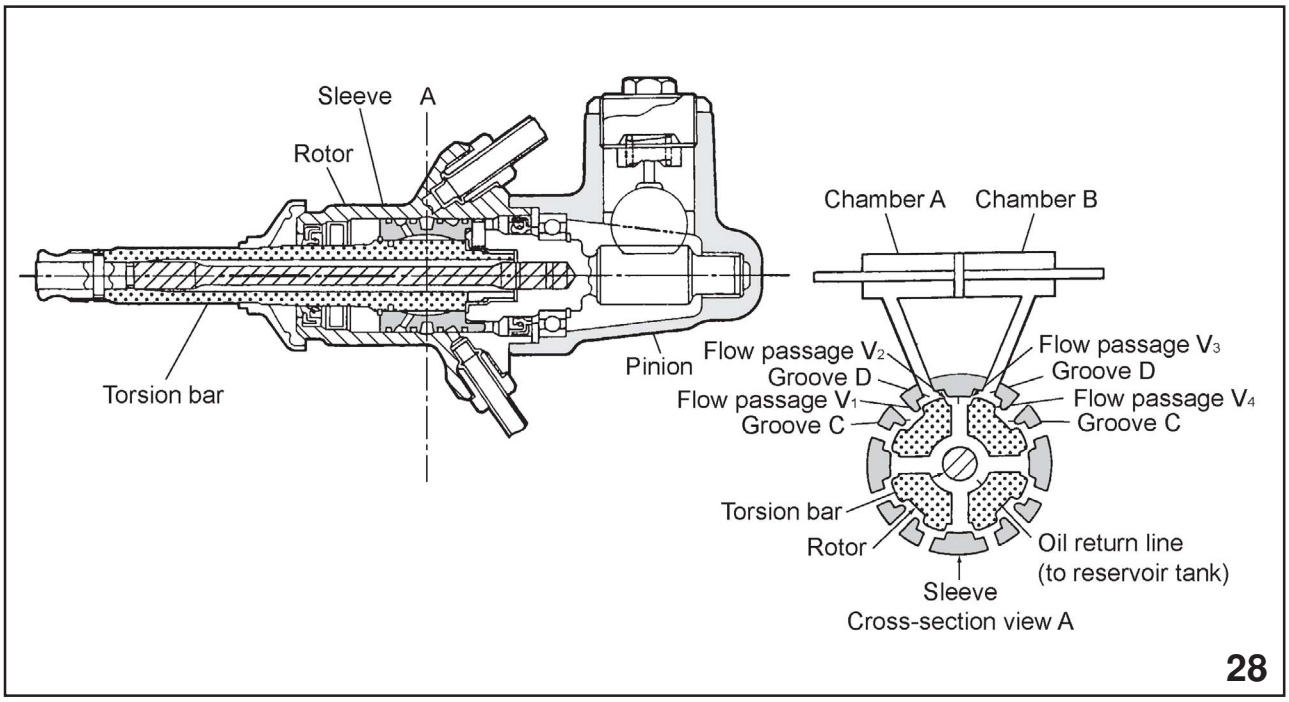
When oil pressure is not produced due to oil pump breakdown, drive belt damage, or other cause, torque is directly transmitted from the valve rotor through the spline to the pinion.



Control Valve

Control Valve Operation

When the steering wheel is turned to the left or right and the torsion bar twists due to resistance with the road surface, the rotor connected to the steering shaft turns, simultaneously switching between the oil channels to chambers A and B and those from chambers A and B to the reservoir tank.

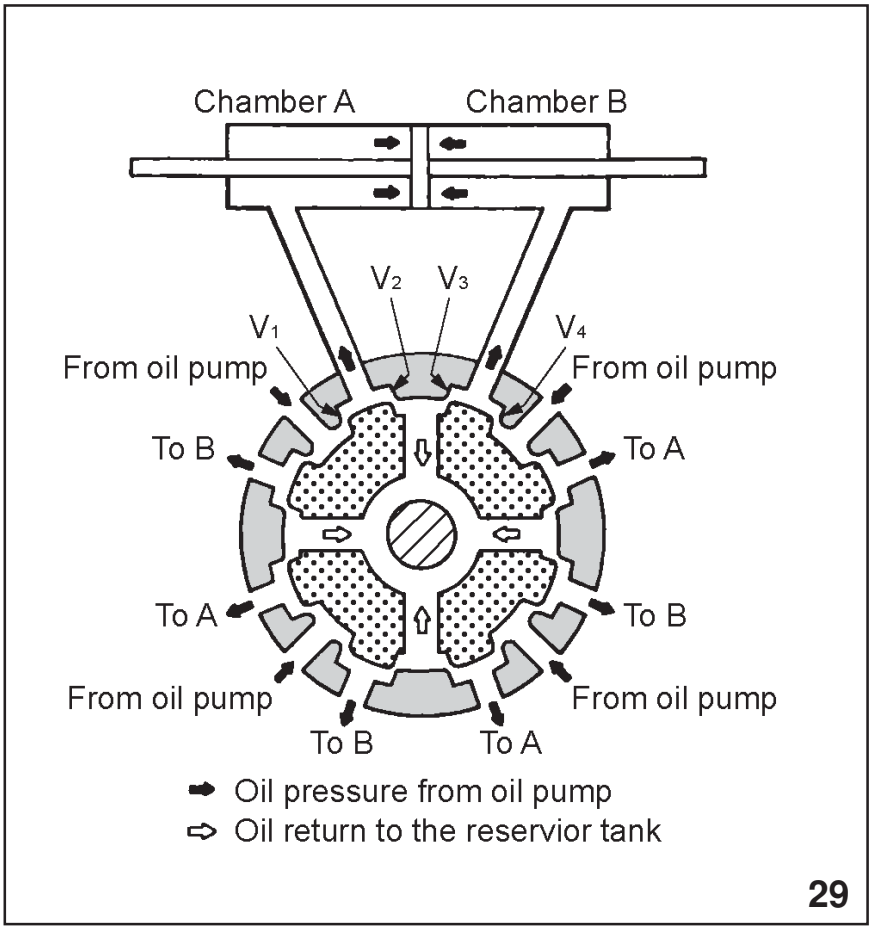


Control Valve Operation

When the steering wheel is in the center position

The torsion bar is not twisted since the steering wheel is in the center position. The rotor and sleeve are in their center positions and oil channels V_1, V_2, V_3, and V_4 have a uniform width. The oil pressure applied to chambers A and B is equal and the steering maintains straight-ahead travel; afterwards, the oil is returned to the reservoir tank.

In this situation, the channel V_1, V_2, V_3, and V_4 are opened widely and oil from the oil pump is drained to the reservoir, keeping oil pressure at a low level.

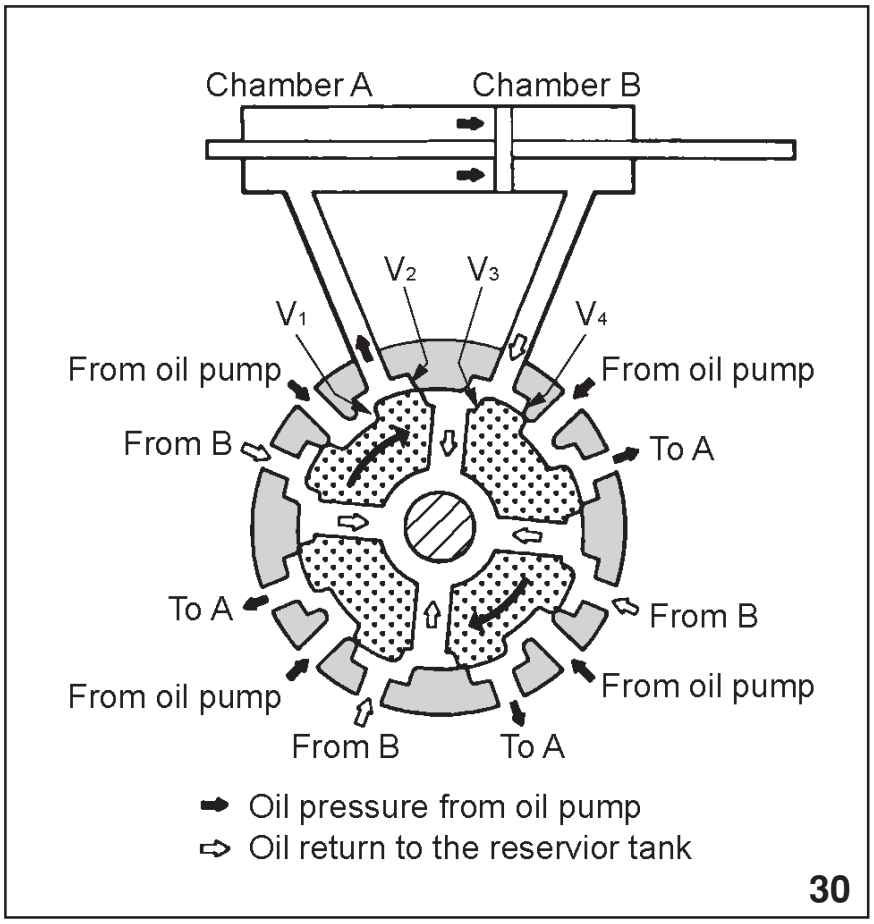


Center Position

When the steering wheel is turned to the right

As the steering wheel is turned to the right, the twisting of the torsion bar causes the rotor to move, closing off oil channels V_1, V_2, V_3, and V_4 and increasing the width of channels V1, and V_3.

The oil pressurized by the oil pump then enters chamber A, passing through oil channel V_1, while the oil in chamber B is pushed by the piston and returned to the reservoir tank via oil channel V_3. This reduces the steering effort and makes it easier to turn the steering wheel to the right. As is evident from the figure, the channels V_2 and V_4 are closed and there is no way that oil from the oil pump return to the reservoir tank, therefore oil pressure from the oil pump increases to the necessary level to move the rack piston.



Turning to the right

Airbag Steering Column Installation

Review the roll connector phasing procedures listed in the appropriate MY Service Manual.

The roll connector must be phased to the steering system only when the front wheels are centered.

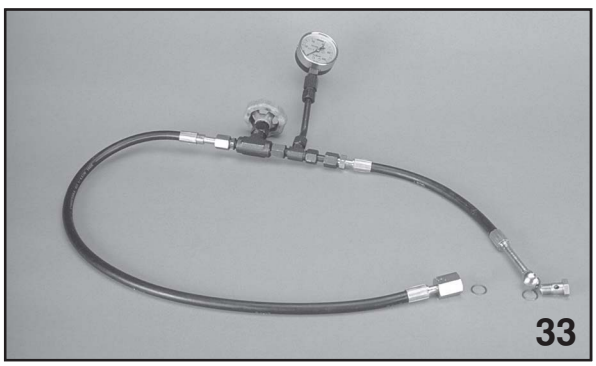
Power Steering System Pressure Testing

Pressure Gauge

If the troubleshooting procedures leads you to suspect a fault in the power steering system, perform a pressure test. Ensure that the vehicle is equipped with the specified tires and rims and that the tires are properly inflated. Then, bring the engine up to operating temperature before performing the test. Keep the following precautions in mind as well:

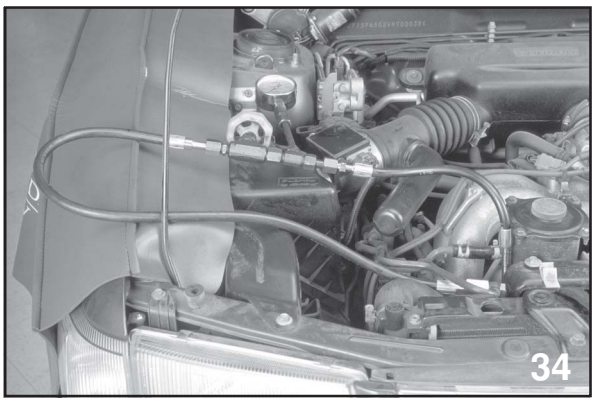
Always wear eye protection

1. Do not leave the pressure gauge valve closed for more than 5 seconds; doing so may damage the pump.
2. Do not hold the steering wheel in the full lock position for longer than 5 seconds; this may damage the pump.
3. Keep the engine speed at idle.
4. Handle ATF fluid carefully; catch spilled fluid with shop cloths to prevent damage to the vehicle's finish.



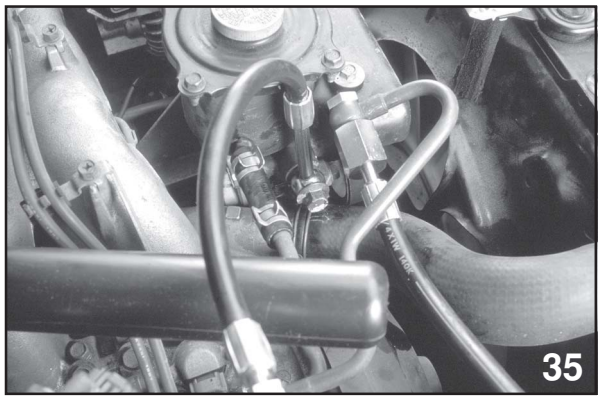
Pressure Gauge with Adapters

Power Steering Pressure Test

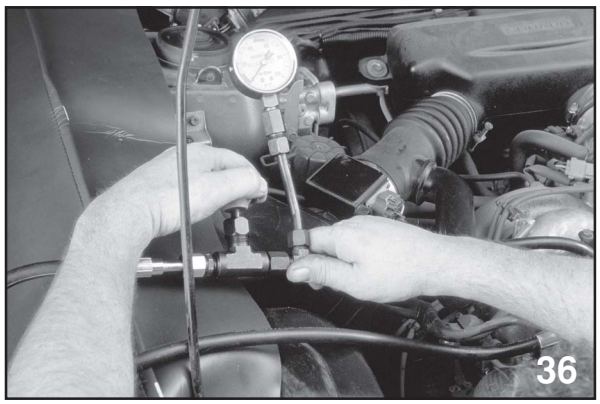


Gauge in place

Attach pressure gauge using the correct hoses to the discharge port of the pump.



Connections at Pump



Opening/closing valve

Then perform the three pressure tests listed.

Step 1: Regular pressure
Engine idling,
valve open:

↓

OK — Not OK → Crimped Fluid line → Replace
Not OK → Leaking fluid line → Tighten or replace
Not OK → Clogged fluid line → Drain or replace

↓

Go to step 2

↓

Step 2: Relief pressure

Engine idling,
valve closed

↓

OK — Not OK → Faulty relief valve
Not OK → Oil pump leak → Replace
Not OK → Worn pump

↓

Go to step 3

Step 3: Working Pressure

Engine idling,
valve open,

steering wheel
turned stop to stop:

↓

OK — Not OK → Faulty control valve → Replace

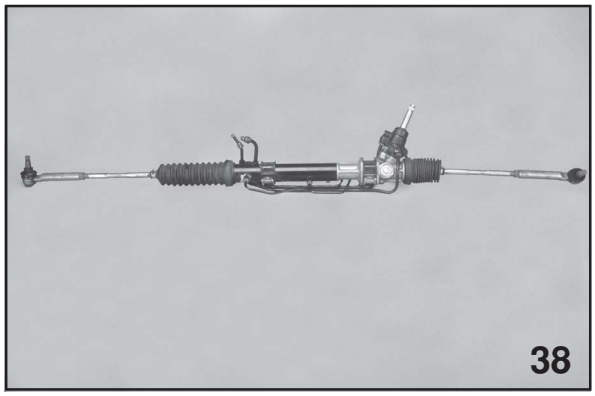
↓

Yes

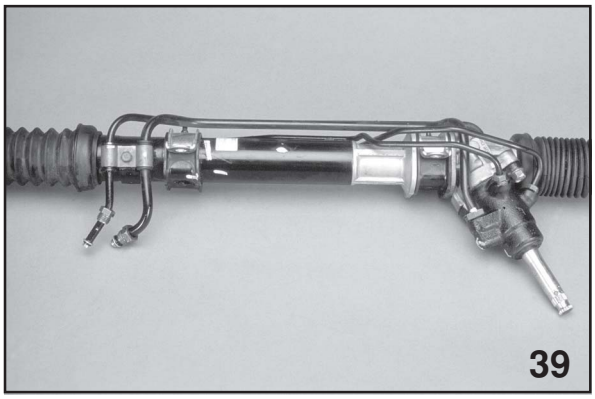
↓

System OK

Steering Rack Overhaul



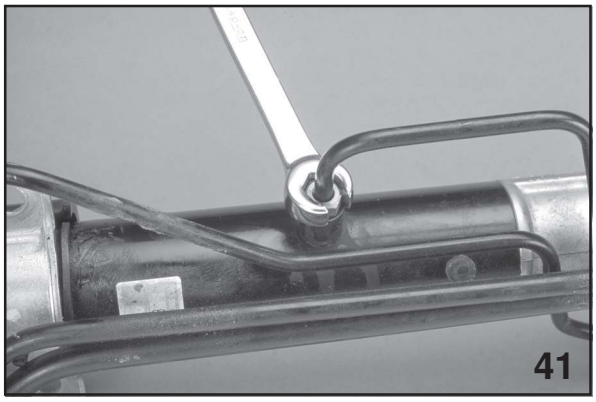
Rack



Pipe Routing

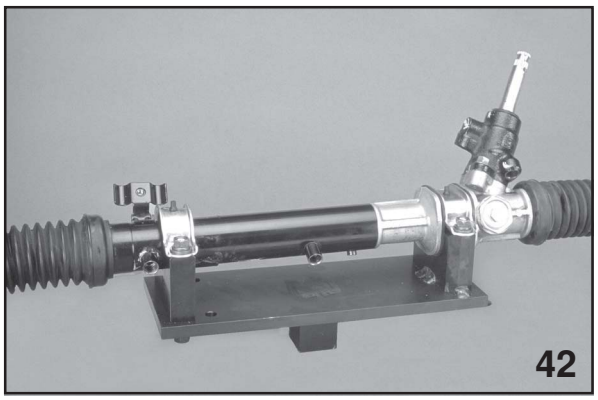
1. 2002 Legacy rack and pinion

Control Valve Connections



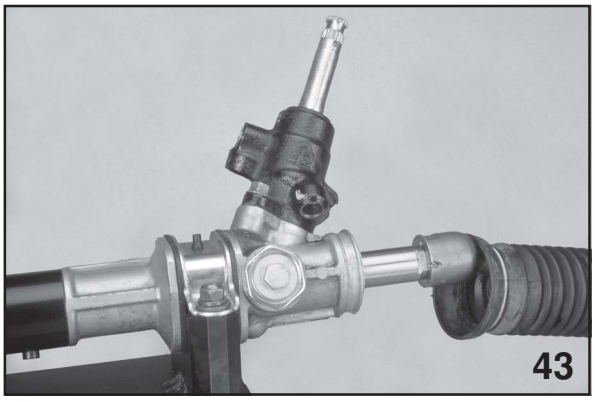
Rack Connections

2. Remove hydraulic lines from rack and pinion



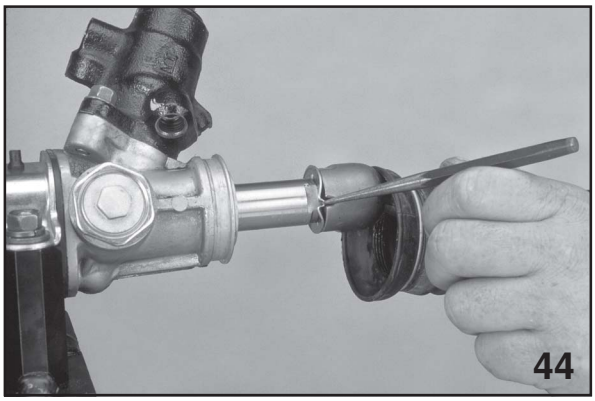
Rack in Holding Tool

3. Mount rack onto rack and pinion fixture. ST 926200000



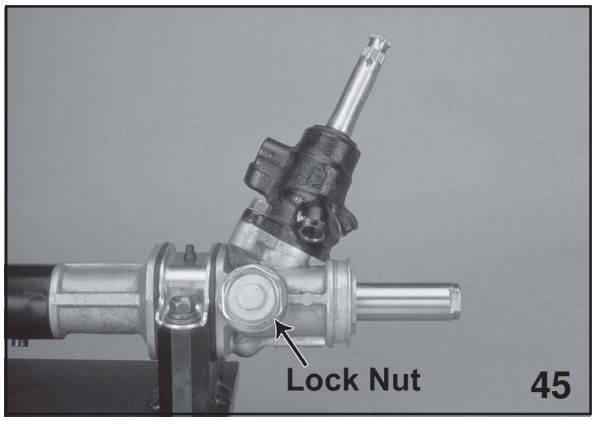
Removing Bellows

4. Remove tie-rod bellows from both sides of rack



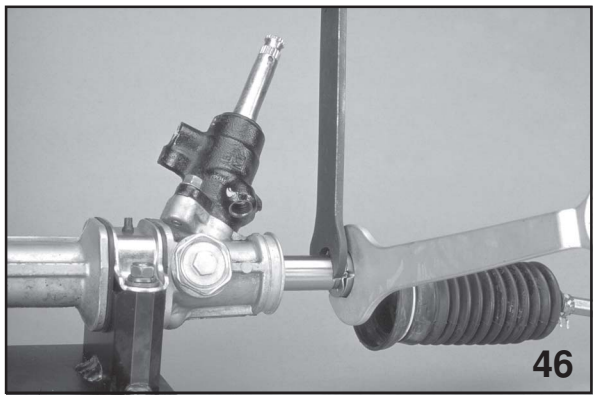
Unstaking Locking Washer

5. Using a hammer and cold chisel, remove stakes from locking washers.



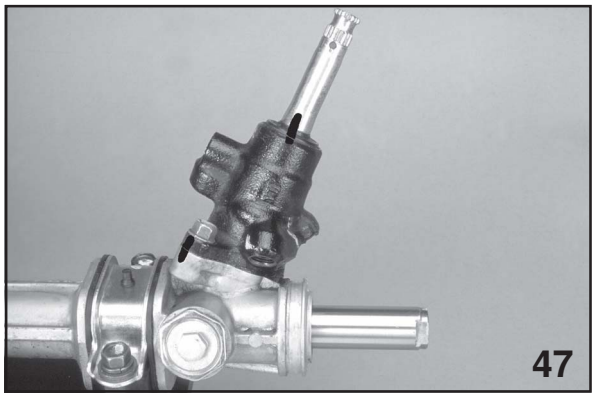
Lock Nut

6. Tighten adjusting nut to assist with holding the rack stationary.



Removing Inner Tie Rods

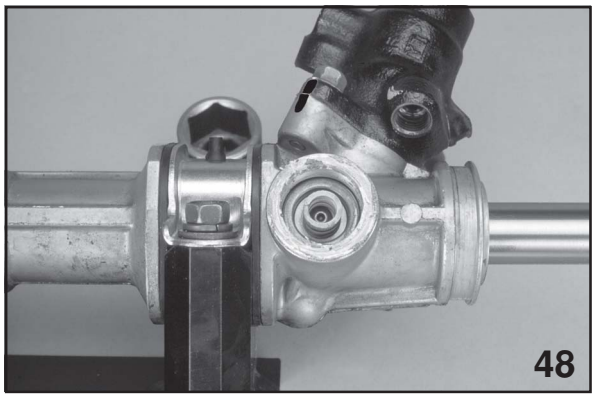
7. Remove inner tie-rods with a 32mm wrench.



Protruding Rack

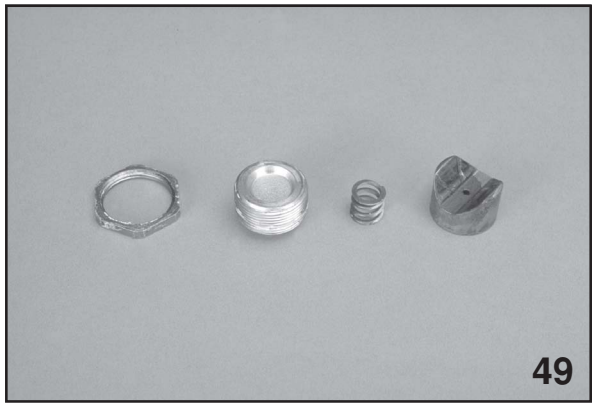
8. Loosen adjusting screw and position drivers side of rack so it protrudes 2.6 inches from rack housing.

   Using paint, mark the relationship of the stubshaft to valve housing and valve housing and rack housing.



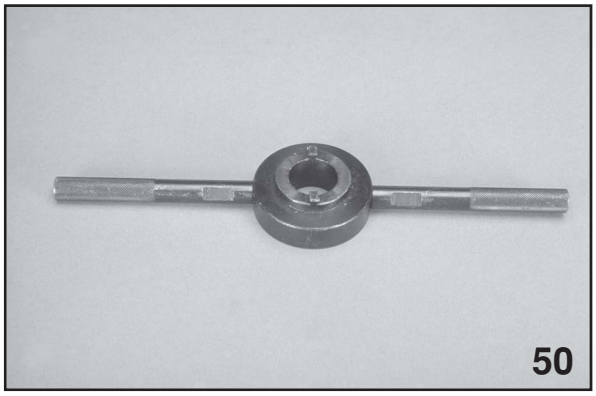
Lock Nut and Adjusting Screw removed

9. Loosen lock nut using ST 926230000



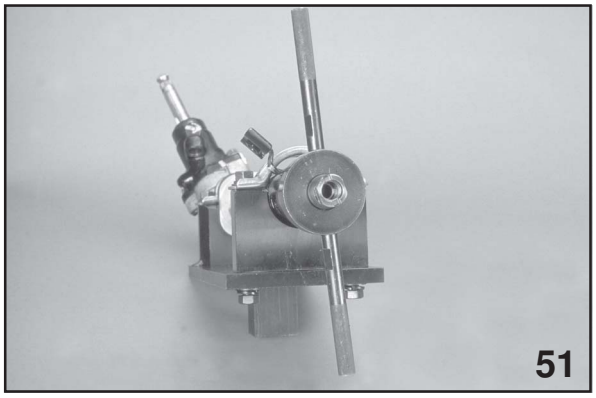
Lock Nut, Adjusting Nut, Spring and Sleeve

10. Remove adjusting nut and sleeve.



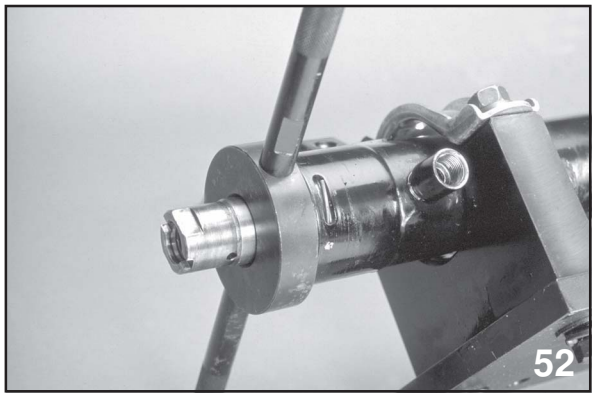
Special Tool

NOTE: TOOL NUMBER VARIES BY MODEL YEAR

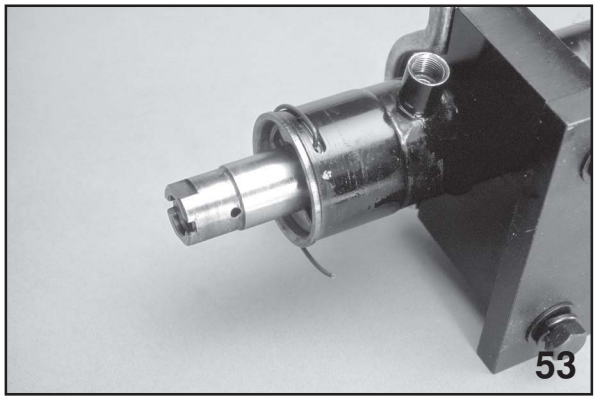


Special Tool usage

11. Using snap ring pliers or special tool, rotate stopper until circlip comes out of stopper.

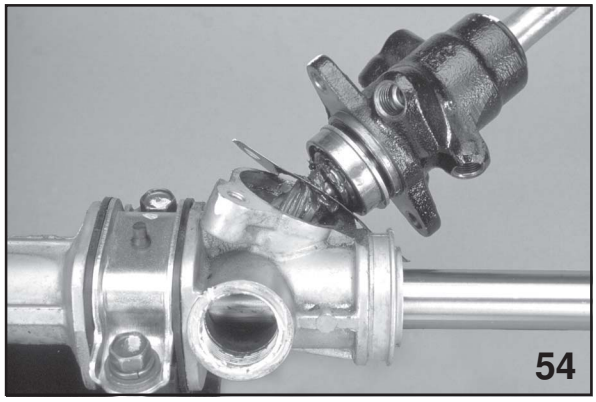


Locate end of Circlip

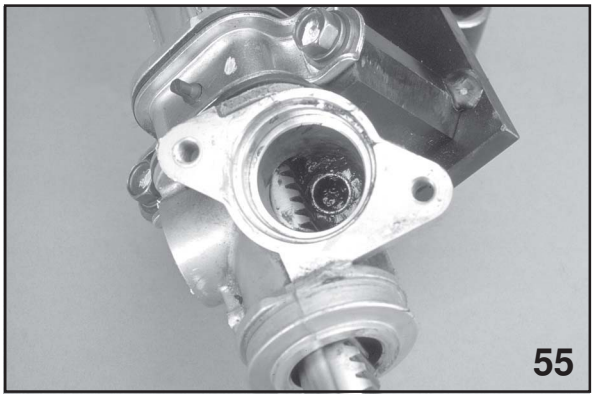


Removing Circlip

12. Rotate circlip in opposite direction and remove it from stopper.

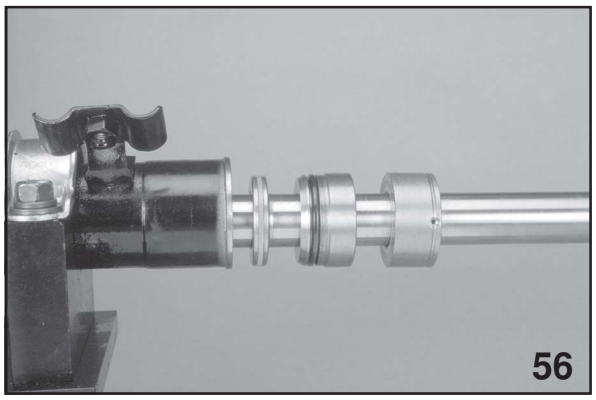


Removing Control Valve



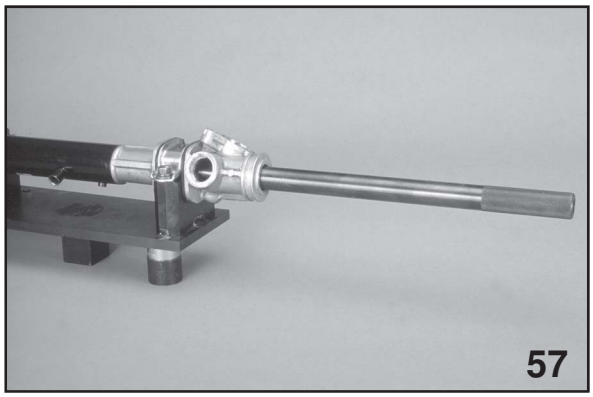
Control Valve Removed

13. Remove two bolts holding valve assembly to rack housing.
14. Remove valve housing from rack.

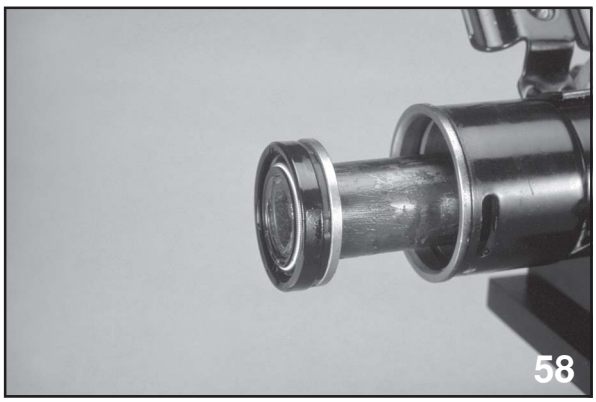


Removing outer Rack Seal

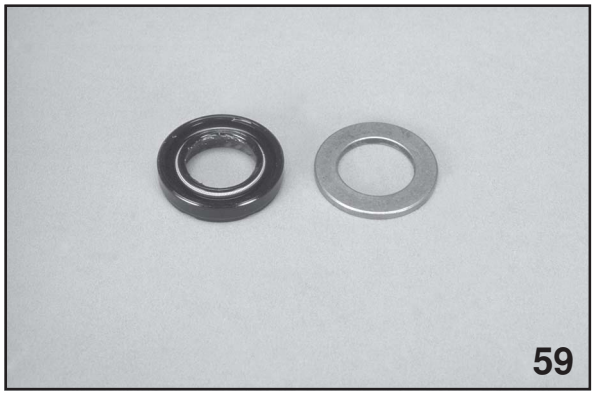
15. Carefully remove rack piston, rack stopper, and rack bushing from rack housing.



Removing Inner Rack Seal

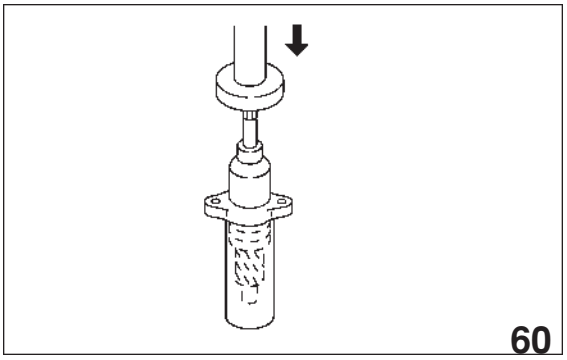


Inner Seal and Backing Washer on tool



Inner Seal and Backing Washer

16. Using ST 34199AE050 remove inner rack seal from rack housing.



Removing Rotary Control Valve

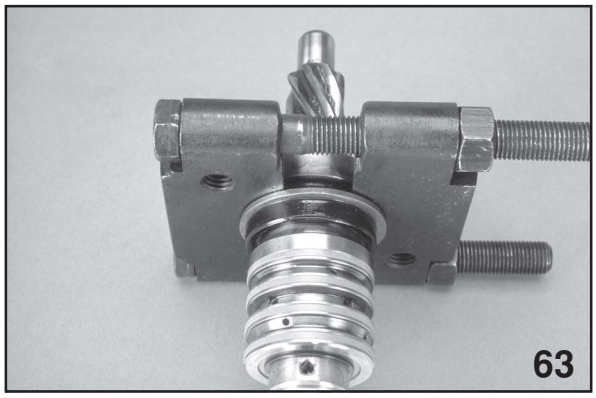
17. Using a press, remove rotary control valve from control valve housing.

Dust Seal

18. Pry dust seal from valve housing.

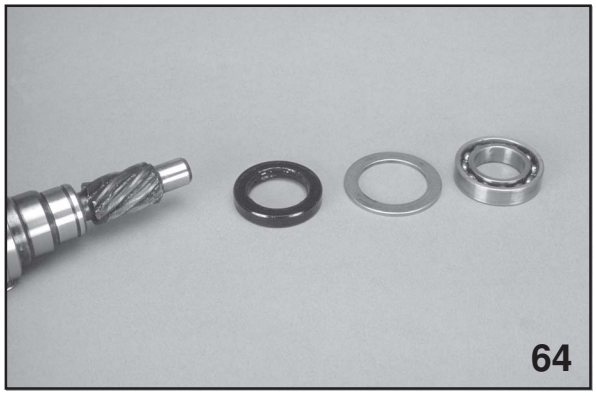
Snap Ring and Upper Seal

19. Remove snap ring from top of valve housing and pry out upper seal with a screwdriver.



Removing Lower Bearing

20. Using a press, remove lower bearing and backing washer from rotary control valve. This is necessary to replace the lower seal on the rotary control.



Lower Seal and Bearing

21. Remove lower seal from rotary control valve.

Upper Seal

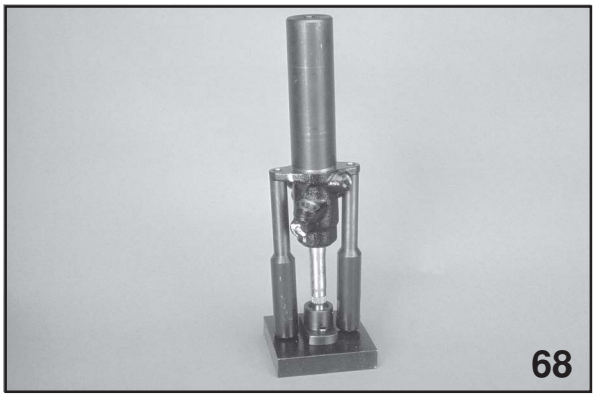
22. Using ST 927610000, install new upper seal in rotary control valve housing. Coat seal with Dexron III before installation.

Snap Ring

23. Install snap ring to retain new seal.
24. Wrap splines of stub with electrical tape.

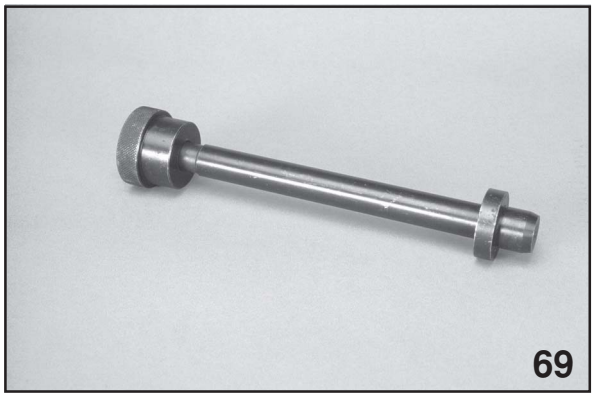
Installing Rotary Control Valve

25. Install rotary control valve into housing.

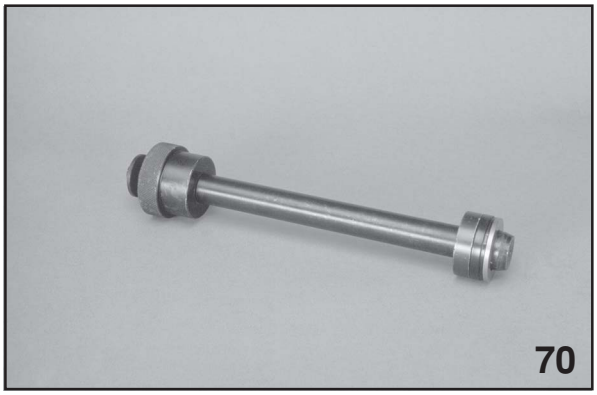


Installing Lower Seal

26. Using ST 926370000, 927630000, 927620000 to install new lower seal in rotary control valve housing.
27. While housing is still installed in fixture, install new backing washer and new ball bearing onto rotary control valve using ST 927640000.
28. Lubricate pinion and bearing with Moly grease included in kit.

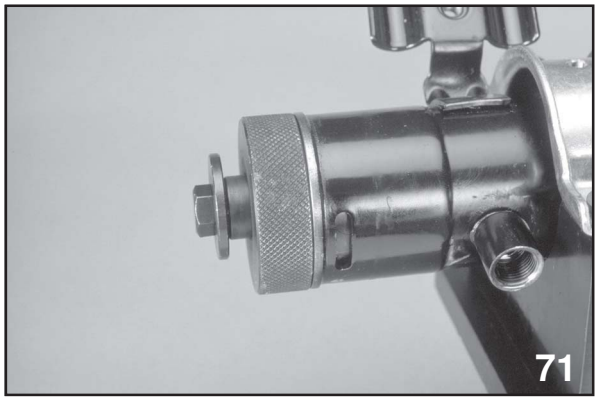


Inner Seal Tool

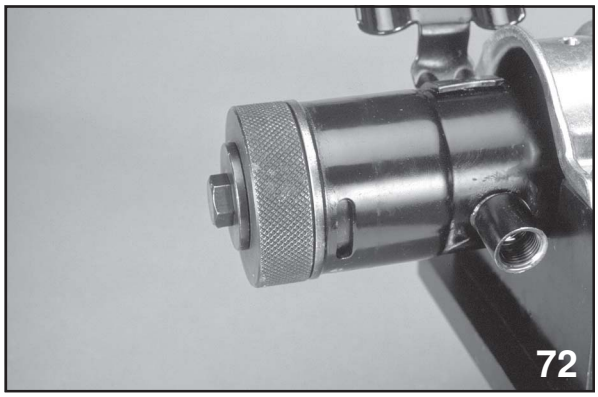


Inner Seal and Backing Washer on tool

29. Install new rack housing inner seal onto ST 34199AE050. Lubricate with Dexron III before installation.

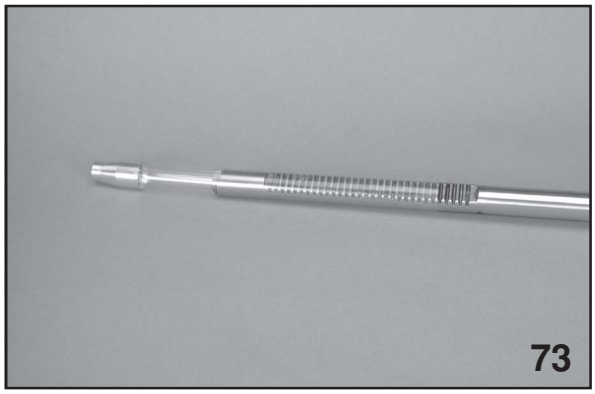


Inner Seal Tool in Rack Housing

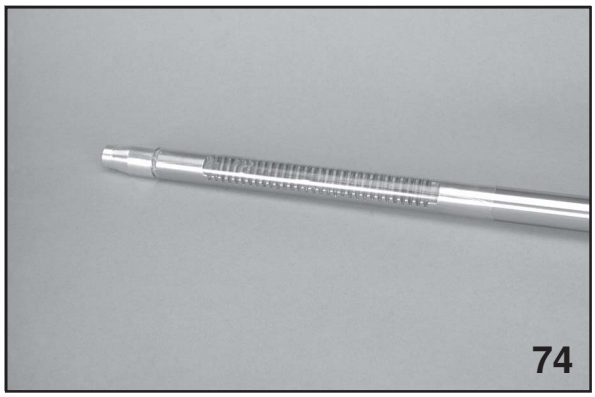


Inner Seal Installed

30. Install inner seal into rack housing.

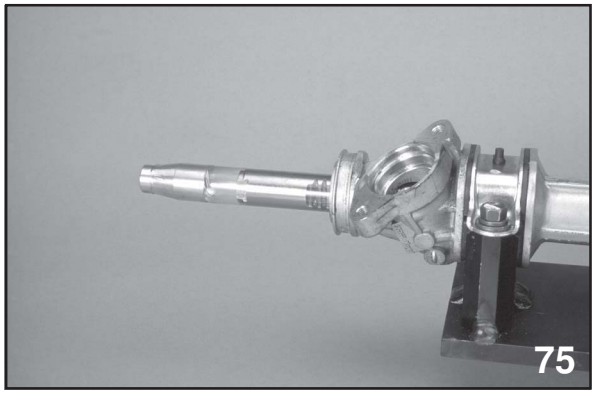


Rack Cover

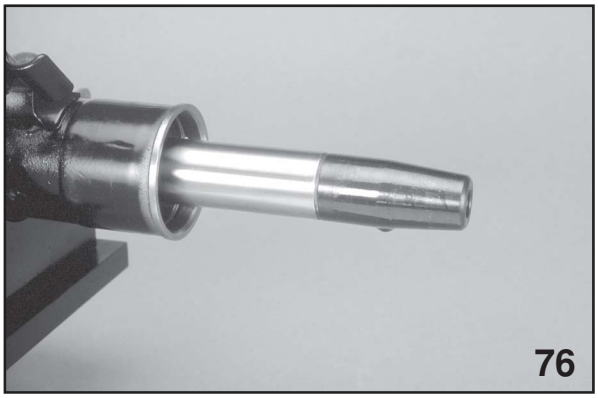


Rack Cover installed

31. Cover rack teeth with ST 926390001.

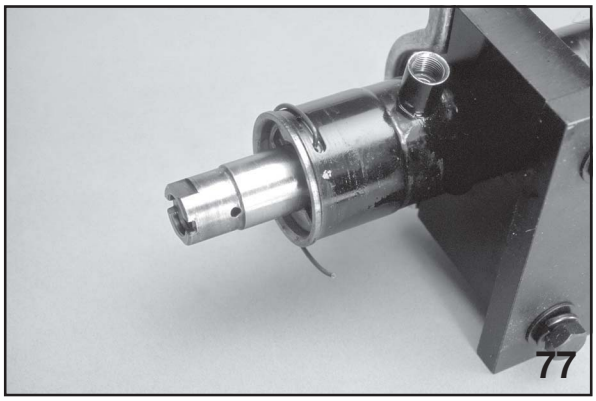


Installing Rack into Rack Housing



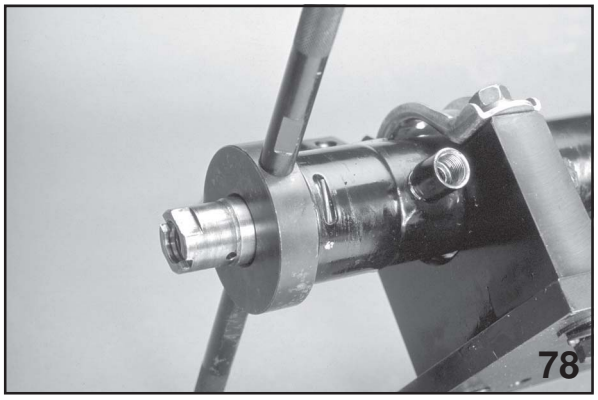
Remove Rack Cover

32. Carefully install rack piston into rack housing sliding it through inner seal.
33. Pack rack teeth with moly grease included in kit.
34. Adjust rack piston so it protrudes from drivers side of rack housing 2.6 inches. Install rotary control valve and housing. Before installation line up marks on valve with those on housing. After installation, insure all marks line up.



Circlip installation

35. Using ST 926400000, and 927660000 install new rack bushing and stopper into rack housing. Install stopper in to housing until inner groove on housing lines up with outer groove on stopper. Lubricate rack bushing with Dexron III before installation.

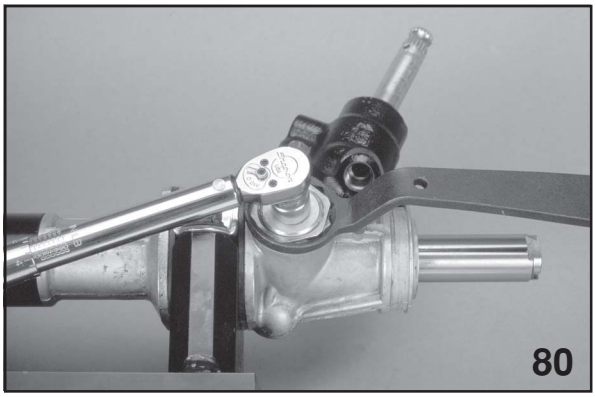


Circlip Tool

36. Install new circlip wire into rack stopper.

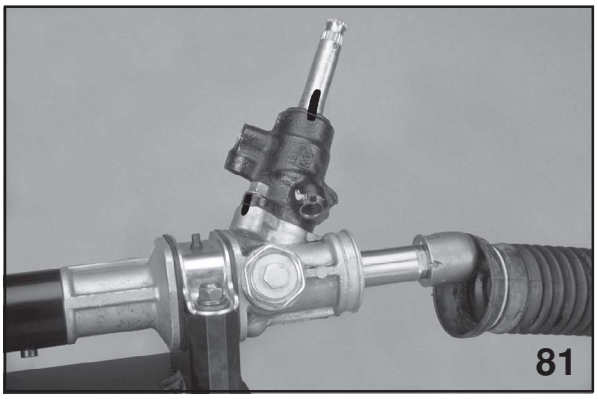
Circlip installation complete

37. Using snap ring pliers rotate stopper to draw in circlip wire. Rotate stopper 90 degrees after circlip wire has drawn in.
38. Lubricate adjusting sleeve with moly grease and install sleeve, spring and adjusting screw into rack housing.
39. Coat threads of adjusting screw with Three bond 1141.



Torquing Adjusting Nut

40. Torque adjusting nut to 65 in. lbs. Repeat this process several times to insure proper contact.
41. After torquing adjusting nut, back off 25° degrees.
42. Install locknut and torque to 29 ft. lbs.



Installing Inner Tie Rods

43. Using new stake washers, reinstall tie rod ends and stake washers down with chisel.
44. Remove rack from holding fixture and reinstall hydraulic lines. Use new O-rings on lines before installation.

Special Tools

926400000-Guide
927660000-Guide
925700000-Wrench
926200000-Stand
926230000-Spanner
926250000-Guide
926340001-Wrench
9276100000-Installer
927620000-Installer
927630000-Installer base
927640000-Installer
927650000-Installer
926390001-Cover
34199AE060-Installer (seal)

Copper gaskets for Power Steering Adaptor hose-PN 34621AC021

Materials

34099PA110 Sealant
004403004 Fuji Bond

Props

Power steering racks
Power steering equipped vehicle(s)
power steering fluid
Tire pressure gauge

Reference Materials

Subaru Service Manuals
Technicians Reference Booklet
Technicians Worksheets

Notes and Cautions

Steering Column Removal

Always refer to the appropriate MY Subaru Service Manual and follow the procedures for removal of the SRS "Airbag" Module prior to any repair and servicing or removal of the steering wheel and steering column from all "Airbag" equipped Subaru vehicles.

Always disconnect the U-bolts before loosening the column mounting bolts.

Disconnect the wiring harness connectors before removing the column.

Remove the XT column carefully to avoid damaging the meter and instrument panel.

Steering Gearbox Overhaul

Do not crimp the pipes.

Do not scratch the rack or the cylinder.

Do not clog the air passages with grease.

Coat the seal and bushings with ATF fluid before installing them.

Install the seals with their lips toward the pressure area.

Use the correct special tools.

Service Bulletins

No.	Date	Title	Subject
04-11-04	01/15/04	2000-2002MY Legacy Sedan, Wagon and Outback Vehicles w/ 2.5L Engines	Power Steering Hose-New style

Tech TIPS

Date	Subject
01/97	Steering Rack Noise
03/97	Power Steering Pump Replacement
10/03	2004MY Impreza and Forester Steering Column Cover
10/03	Parts Ordering Update for VSC Steering Angle Sensor


CERTIFIED
SUBARU
TECHNICIAN


AUTOMOTIVE
Youth
Educational
Systems
YES
PROUD PARTNER