

## 2. Power Steering System

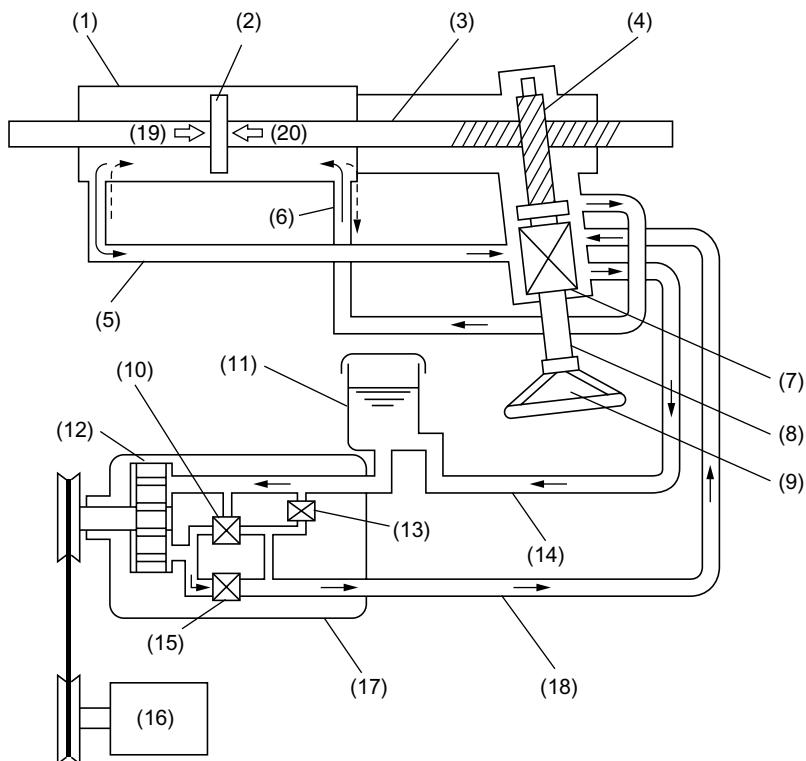
### A: HYDRAULIC SYSTEM

- The fluid pump is directly driven by the engine through a belt.
- When the steering wheel is not being turned, the pressure-sensitive valve in the pump opens to drain the fluid into the fluid reservoir tank.
- The fluid pressure is maintained almost constant regardless of change in the engine speed by the function of the flow control valve. The pressure-regulated fluid is delivered to the control valve via hose A.
- When the steering wheel is turned, the rotary control valve connected to the pinion shaft opens the hydraulic circuit corresponding to the direction in which the steering wheel is turned. The fluid then flows into chamber A or B via pipe A or B.
- The fluid pressure in chamber A or B acts on the rack piston in the same direction as that in which the rack shaft is moved by rotation of the steering wheel. This helps reduce the effort required of the driver to operate the steering wheel.
- Movement of the rack piston causes the fluid in the other chamber to return to the reservoir tank via pipe A or B, control valve, and hose B.
  - As the steering shaft is connected to the pinion shaft mechanically via the rotary control valve, the steering system can be operated as a manual system even if the hydraulic system becomes inoperative.
  - To control the maximum fluid pressure, a relief valve is built into the fluid pump to prevent build-up of an excessive fluid pressure.

# POWER STEERING SYSTEM

## POWER ASSISTED SYSTEM (POWER STEERING)

### 2.5 L model



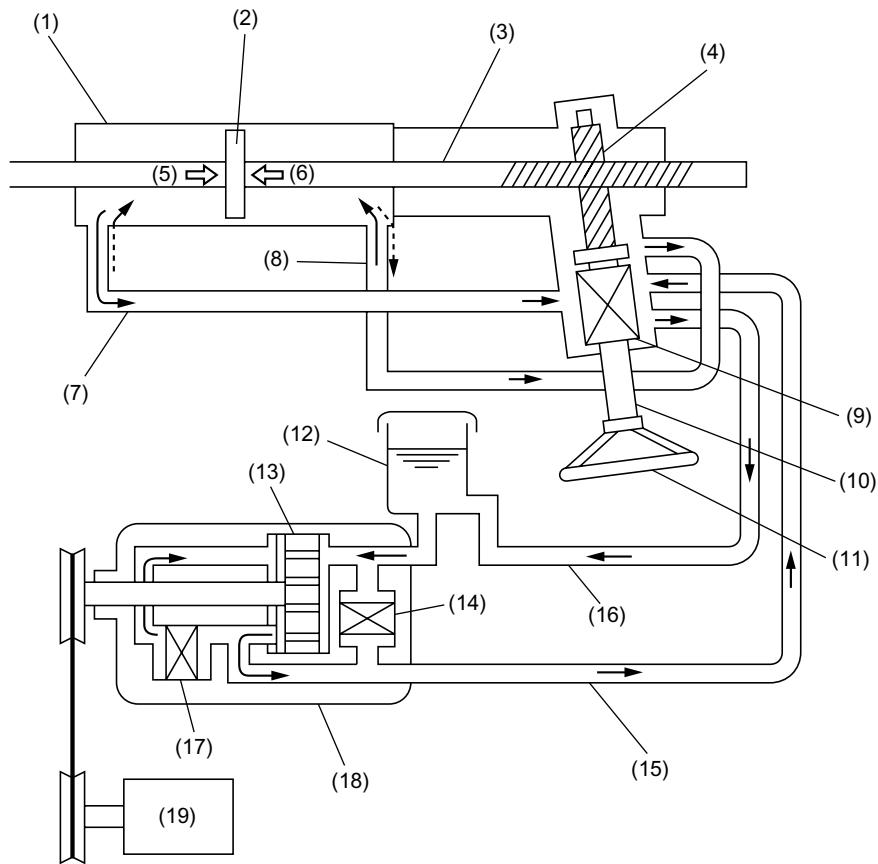
PS-00247

(1) Power cylinder	(8) Steering shaft	(15) Flow control valve
(2) Rack piston	(9) Steering wheel	(16) Engine
(3) Rack shaft	(10) Pressure-sensitive valve	(17) Fluid pump
(4) Pinion shaft	(11) Tank	(18) Hose A
(5) Pipe A	(12) Vane pump	(19) Chamber A
(6) Pipe B	(13) Relief valve	(20) Chamber B
(7) Rotary control valve	(14) Hose B	

# POWER STEERING SYSTEM

## POWER ASSISTED SYSTEM (POWER STEERING)

### 3.0 L model



PS-00009

(1) Power cylinder	(11) Steering wheel
(2) Rack piston	(12) Tank
(3) Rack shaft	(13) Vane pump
(4) Pinion shaft	(14) Relief valve
(5) Chamber A	(15) Hose A
(6) Chamber B	(16) Hose B
(7) Pipe A	(17) Pump control valve
(8) Pipe B	(18) Fluid pump
(9) Rotary control valve	(19) Engine
(10) Steering shaft	

# POWER STEERING SYSTEM

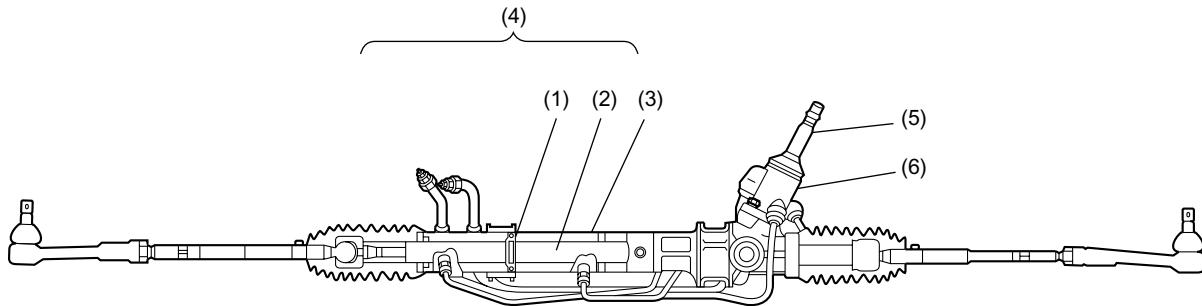
## POWER ASSISTED SYSTEM (POWER STEERING)

### B: GEARBOX ASSEMBLY

#### 1. POWER CYLINDER

The gearbox integrates the control valve and power cylinder into a single unit. The rack shaft serves as a power cylinder piston. The rotary control valve is located around the pinion shaft.

The rotary control valve and power cylinder are connected to each other by two pipes through which hydraulic fluid flows.



PS-00483

(1) Piston

(2) Rack shaft

(3) Cylinder

(4) Power cylinder

(5) Pinion shaft

(6) Control valve

## POWER STEERING SYSTEM

### POWER ASSISTED SYSTEM (POWER STEERING)

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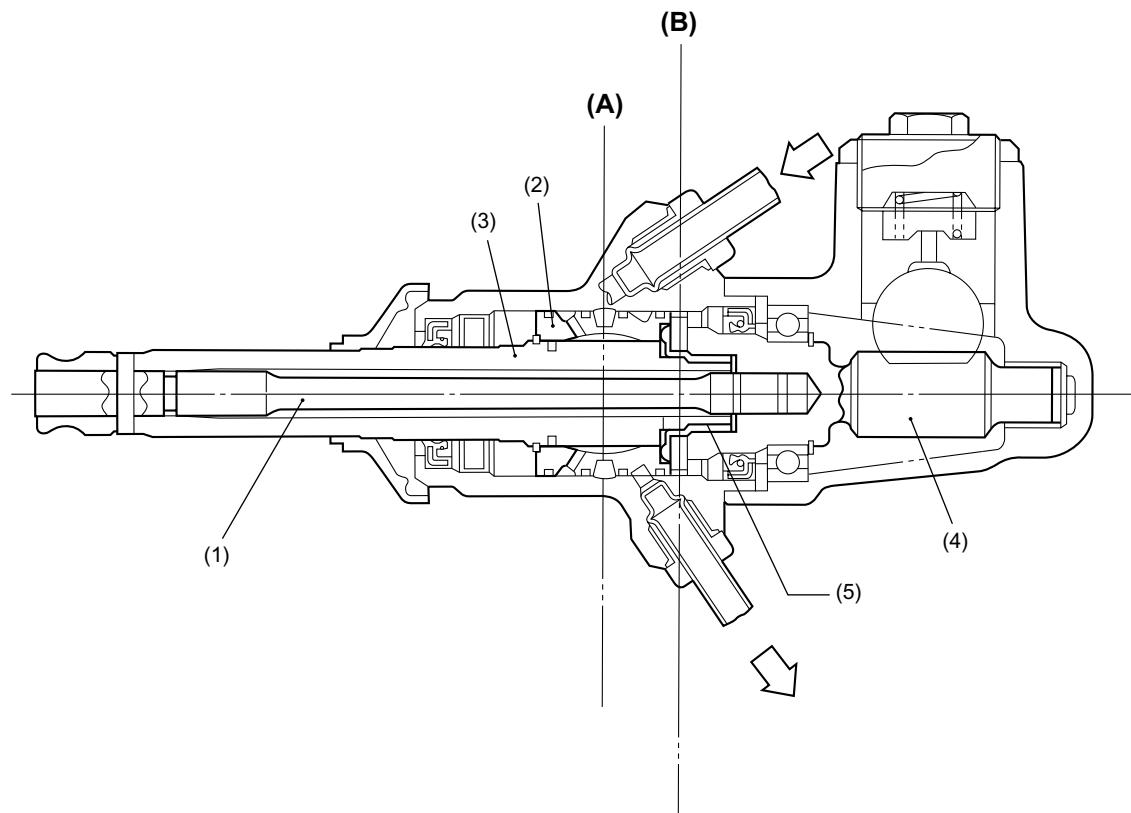
#### 2. ROTARY CONTROL VALVE

The rotary control valve consists of a rotor (which rotates together with the steering shaft), a pinion (which is connected to the rotor and torsion bar), and a sleeve (which rotates together with the pinion). The rotor and sleeve have grooves C and D, respectively, which form fluid passages V<sub>1</sub> through V<sub>4</sub>.

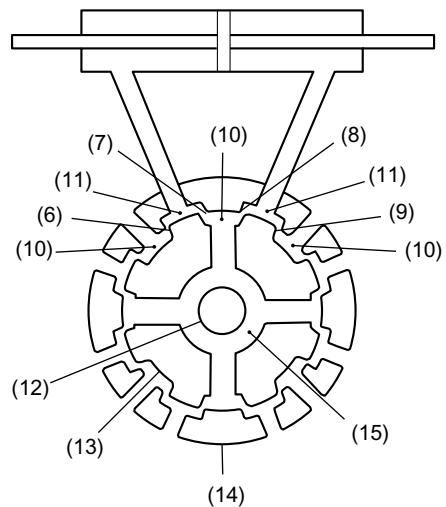
The pinion is in mesh with the rotor with adequate clearance, which enable the rack to be moved manually by rotating the steering shaft (fail-safe feature).

# POWER STEERING SYSTEM

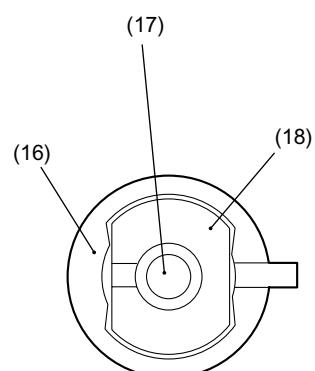
## POWER ASSISTED SYSTEM (POWER STEERING)



(A)



(B)



PS-00250

# POWER STEERING SYSTEM

## POWER ASSISTED SYSTEM (POWER STEERING)

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(1) Torsion bar	(12) Torsion bar
(2) Sleeve	(13) Rotor
(3) Rotor	(14) Sleeve
(4) Pinion	(15) Fluid return line (to reservoir tank)
(5) Pinion-to-rotor engagement (fail-safe feature)	(16) Pinion
(6) Fluid passage $V_1$	(17) Torsion bar
(7) Fluid passage $V_2$	(18) Rotor
(8) Fluid passage $V_3$	
(9) Fluid passage $V_4$	<b>(A)</b> Cross-sectional view A (fluid passage switching circuit)
(10) Groove C	<b>(B)</b> Cross-sectional view B (pinion-to-rotor engagement)
(11) Groove D	

# POWER STEERING SYSTEM

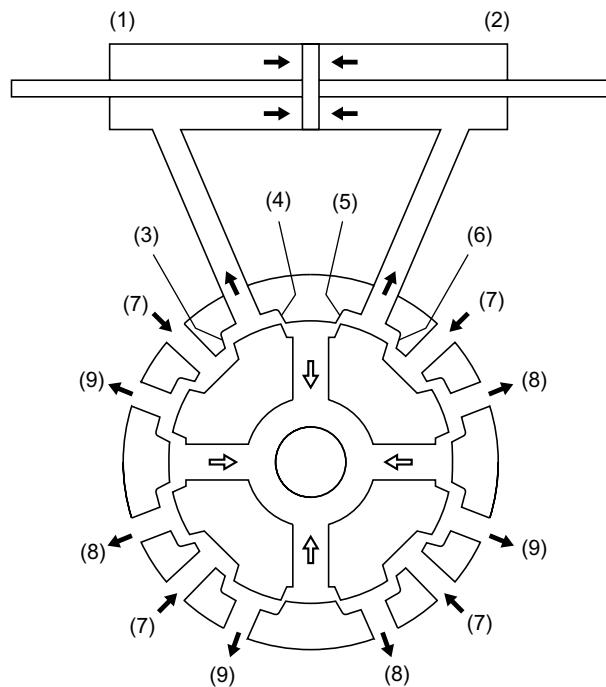
## POWER ASSISTED SYSTEM (POWER STEERING)

- Principle of operation

When the torsion bar is twisted by a rotational force applied to the steering wheel, the relative position between the rotor and sleeve changes. This changes the cross-sectional area of fluid passages  $V_1$ ,  $V_2$ ,  $V_3$  and  $V_4$ . The fluid passages are thus switched and the fluid pressure is controlled in accordance with the operation of the steering wheel.

- When no steering force is applied:

The rotor and sleeve are held at the neutral position. Fluid passages  $V_1$ ,  $V_2$  and  $V_3$ , which are formed by grooves C and D are open equally. Under this condition, the fluid from the pump returns to the reservoir tank so that neither fluid pressure builds up nor the rack piston moves in the power cylinder.



PS-00012

(1) Chamber A

(4)  $V_2$

(7) From fluid pump

(2) Chamber B

(5)  $V_3$

(8) To A

(3)  $V_1$

(6)  $V_4$

(9) To B

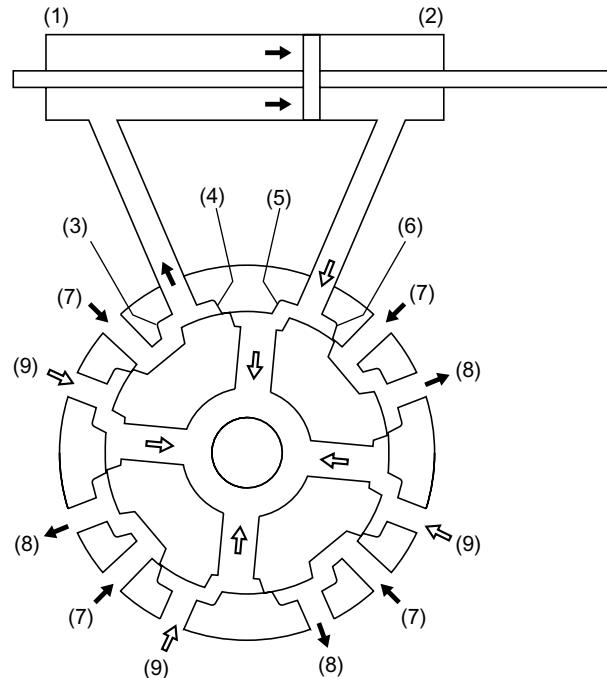
# POWER STEERING SYSTEM

## POWER ASSISTED SYSTEM (POWER STEERING)

- When steering force is applied:

When the steering wheel is turned to the right, for example, fluid passages  $V_1$  and  $V_3$  are opened while fluid passages  $V_2$  and  $V_4$  are nearly closed.

At this point, the fluid pressure in chamber A of the power cylinder increases depending on the degree of closure of fluid passages  $V_2$  and  $V_4$  so that the rack piston moves to the right. The fluid in chamber B, on the other hand, is drained through fluid passage  $V_3$  into the reservoir tank.



PS-00013

- (1) Chamber A
- (2) Chamber B
- (3)  $V_1$

- (4)  $V_2$
- (5)  $V_3$
- (6)  $V_4$

- (7) From fluid pump
- (8) To A
- (9) From B

# POWER STEERING SYSTEM

## POWER ASSISTED SYSTEM (POWER STEERING)

### C: FLUID PUMP AND RESERVOIR TANK

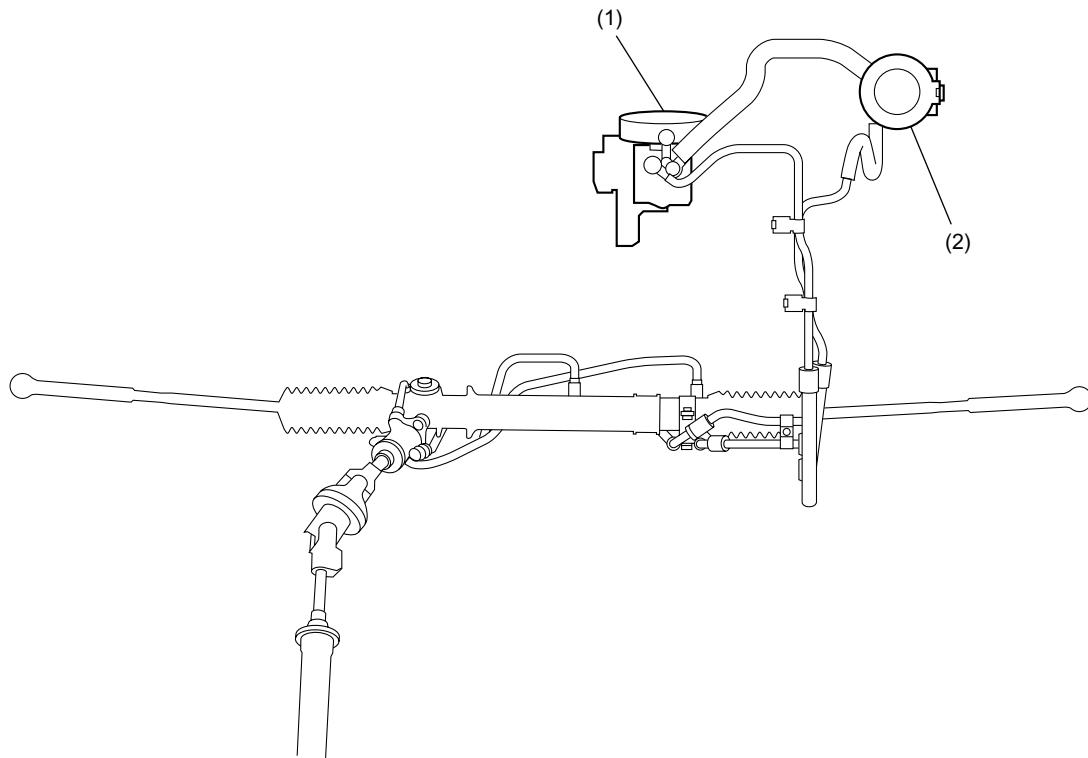
#### 1. 2.5 L MODEL

The fluid pump is a vane type driven by the engine via belt.

The reservoir tank is mounted on the vehicle body.

The fluid pump incorporates the flow control valve, pressure-sensitive valve, and relief valve, each performing the following functions:

- The flow control valve regulates the flow rate of discharged fluid to a constant level irrespective of the engine speed.
- The pressure-sensitive valve returns the fluid to the reservoir tank when there is no steering input.
- The relief valve protects the system from an excessively high pressure which may occur, for example, when the steering wheel is turned all the way.

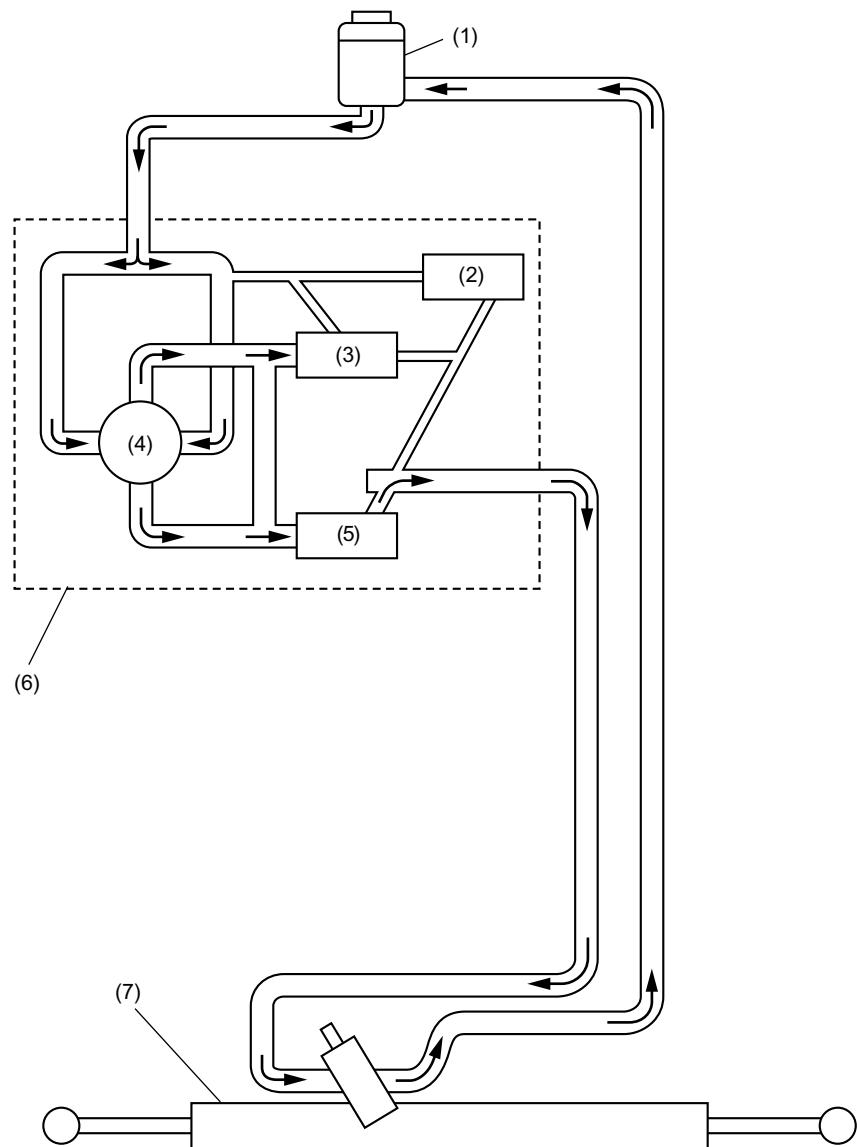


PS-00251

- (1) Fluid pump
- (2) Reservoir tank

# POWER STEERING SYSTEM

## POWER ASSISTED SYSTEM (POWER STEERING)



PS-00252

(1) Reservoir tank

(2) Relief valve

(3) Pressure-sensitive valve

(4) Vane pump

(5) Flow control valve

(6) Fluid pump

(7) Steering gearbox

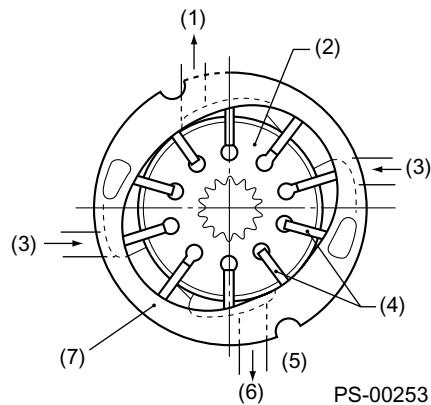
# POWER STEERING SYSTEM

## POWER ASSISTED SYSTEM (POWER STEERING)

### • Vane pump

The vane pump consists of a rotor, a cam ring, and 10 vanes.

When the rotor rotates, the vane movably fitted in each slot of the rotor is radially moved out by centrifugal force and pressed against the inside wall of the cam ring. Since the inside of the cam ring is oval-shaped, the fluid from the suction port is confined and pressurized in the chamber formed between two adjacent vanes as the rotor rotates and is delivered through the discharge port. The pressurized fluid circulates through the hydraulic circuit.



- (1) Discharge
- (2) Rotor
- (3) Suction
- (4) Vane

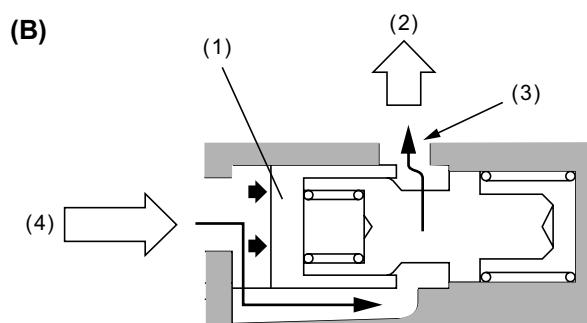
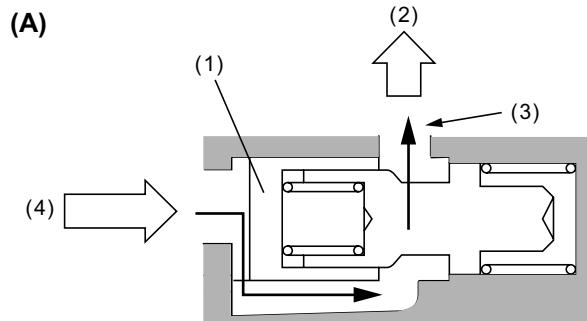
- (5) Vane pump
- (6) Discharge
- (7) Cam ring

# POWER STEERING SYSTEM

## POWER ASSISTED SYSTEM (POWER STEERING)

### ● Flow control valve

The flow control valve consists of a sub-spool which is pushed to the right when the fluid pressure rises as the engine speed increases (and consequently, the pump discharge rate becomes higher). When the sub-spool is shifted to the right, the variable orifice is narrowed, thus the discharge rate is reduced.



PS-00254

(A) Engine speed low

(B) Engine speed high

(1) Sub-spool

(2) To steering gearbox

(3) Variable orifice

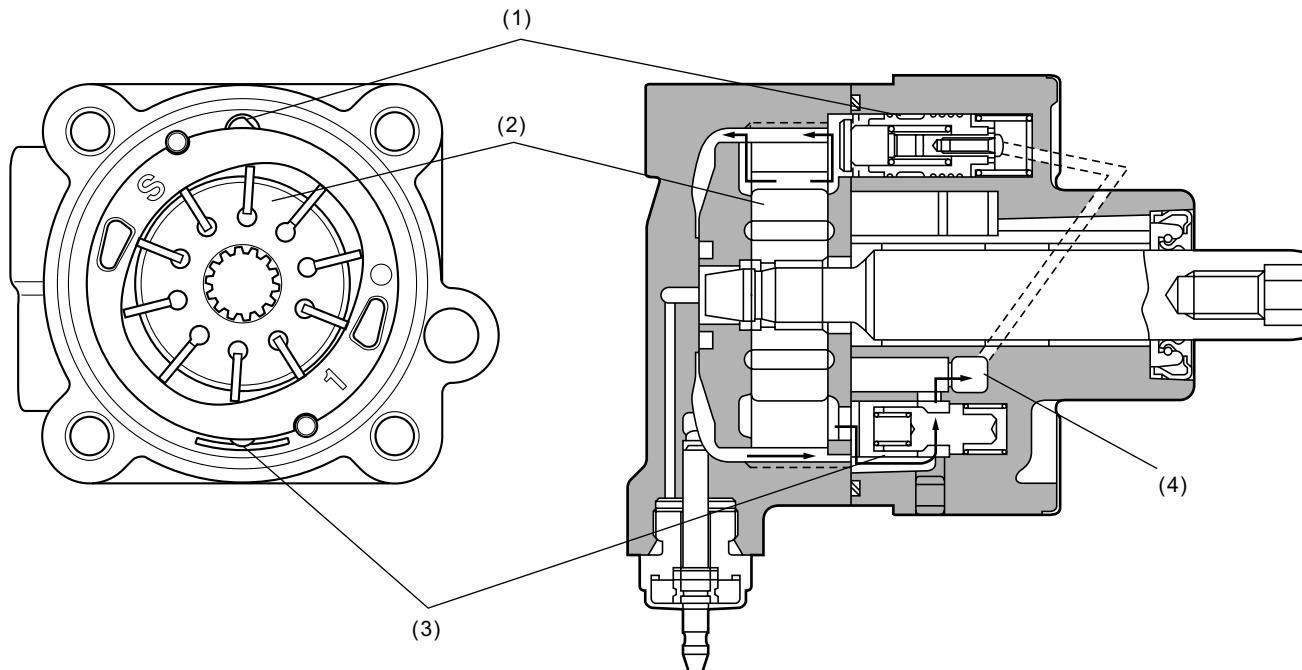
(4) From vane pump

# POWER STEERING SYSTEM

## POWER ASSISTED SYSTEM (POWER STEERING)

### • Pressure-sensitive valve

The pressure-sensitive valve's left end is exposed to the fluid pump discharge-pressure and its right end to the flow control valve outlet pressure (the pressure of the fluid being directed to the steering gearbox).



PS-00255

(1) Pressure-sensitive valve

(2) Fluid pump

(3) Flow control valve

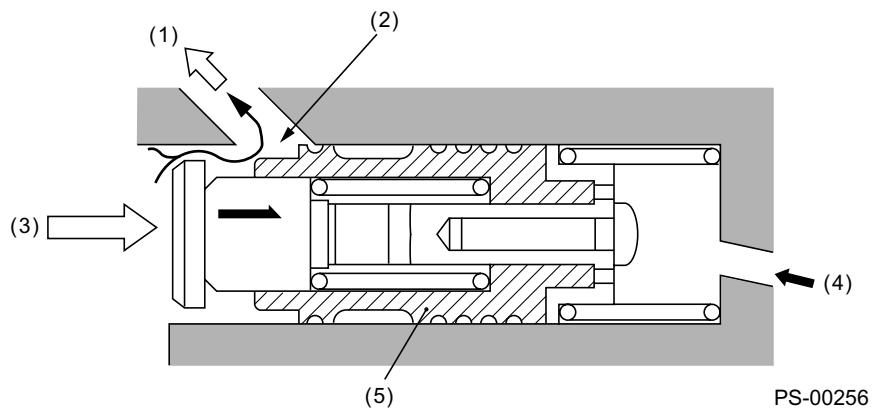
(4) To steering gearbox

## POWER STEERING SYSTEM

### POWER ASSISTED SYSTEM (POWER STEERING)

- When the steering wheel is not being turned, the fluid that has passed through the flow control valve is directed to the steering gearbox but it is returned to the reservoir tank without entering the rotary control valve's passages in the gearbox. Therefore, the pressure acting on the valve's right end does not increase.

On the other hand, the pressure acting on the left end of valve is the fluid pump-discharge pressure which is higher than the pressure acting on the right end. This causes the pressure-sensitive valve's spool assembly to move to the right. As a result, the drain port which was closed by the outer spool is now opened. The pump discharged fluid then flows to the reservoir tank and the pressure inside the pump is reduced.



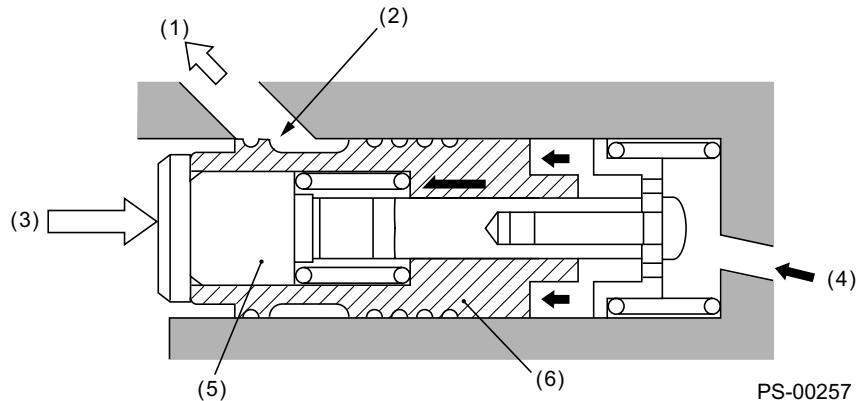
(1) To reservoir tank	(4) Fluid pressure after passing through flow control valve (low)
(2) Drain port open	(5) Outer spool
(3) Pressure from vane pump (high)	

# POWER STEERING SYSTEM

## POWER ASSISTED SYSTEM (POWER STEERING)

- When the steering wheel is turned in either direction, the pressure of the fluid that has passed through the flow control valve and directed into the steering gearbox increases as it enters the power cylinder and acts on the rack piston.

The inner spool of the pressure-sensitive valve is kept pressed to the right by the pump-discharge pressure acting on its left end. On the other hand, the fluid pressure acting on the right end of the valve is also high. So, the outer spool is moved to the left, closing the drain port. As a result, the pump internal pressure increases so that the fluid with a high pressure necessary for power assistance is supplied to the gearbox.



(1) To reservoir tank	(4) Fluid pressure after passing through flow control valve (increase)
(2) Drain port closed	(5) Inner spool
(3) Pressure from vane pump	(6) Outer spool

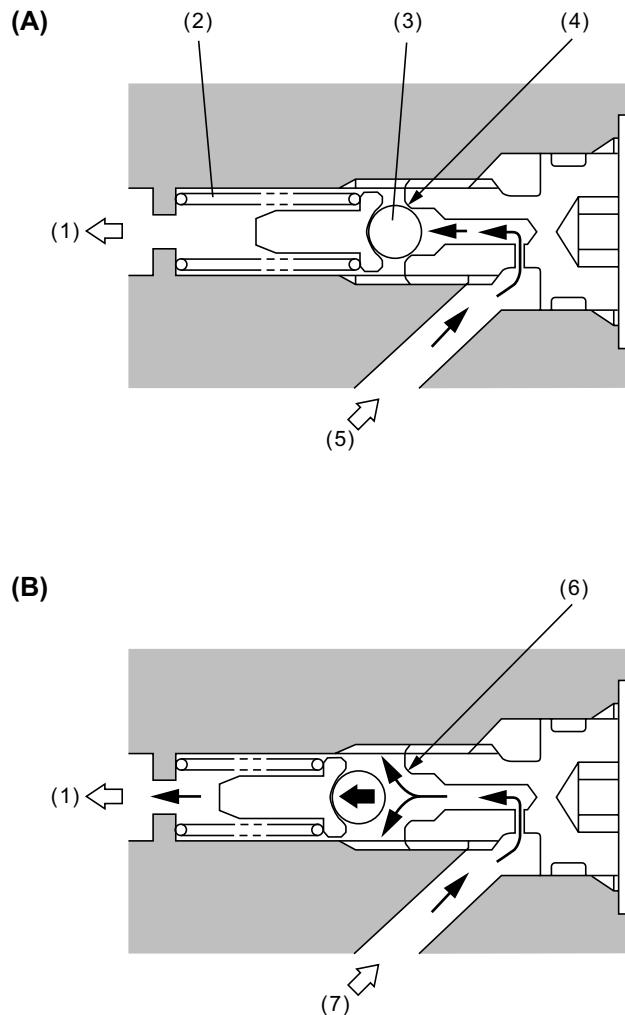
# POWER STEERING SYSTEM

## POWER ASSISTED SYSTEM (POWER STEERING)

### ● Relief valve

The relief valve consists of a check ball and a spring. The check ball is exposed to the fluid pressure that is regulated by the flow control valve (branched from the line to the steering gearbox).

If the pressure acting on the check ball is increased abnormally due to, for example, rotation of the steering wheel to a stop and overcomes the spring tension, the ball is pushed to the left, allowing the fluid to be drained into the reservoir tank. Therefore, the pressure to the steering gearbox is prevented from becoming excessively high.



PS-00258

**(A)** Relief valve not in operation

**(B)** Relief valve in operation

(1) To reservoir tank

(5) Fluid pressure after passing through flow control valve (low)

(2) Spring

(6) Valve open

(3) Check ball

(7) Fluid pressure after passing through flow control valve (higher than preset level)

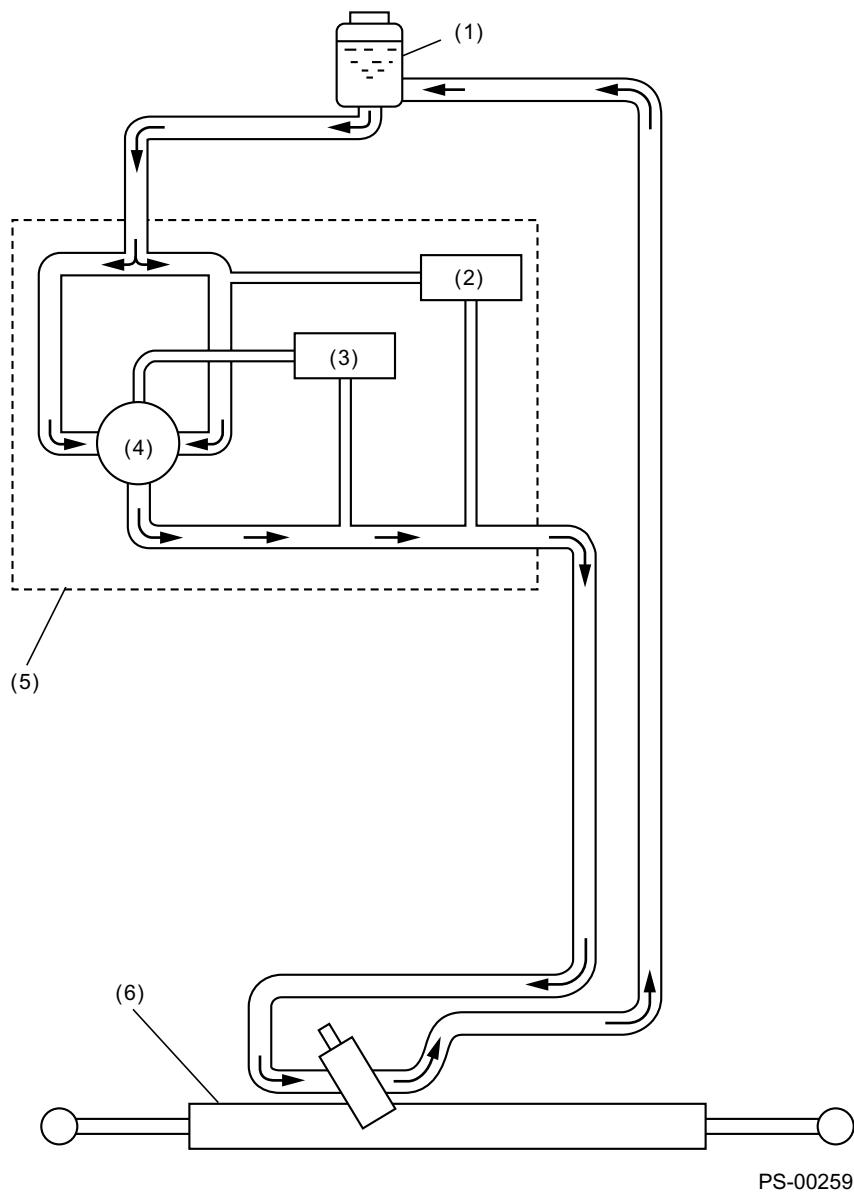
(4) Valve closed

# POWER STEERING SYSTEM

## POWER ASSISTED SYSTEM (POWER STEERING)

### 2. 3.0 L MODEL

- The reservoir tank is mounted on the vehicle body.
- The fluid pump is belt-driven by the engine. The fluid flow is controlled according to the engine speed so that an adequate steering resistance is given during high-speed operation. The fluid pump is a variable capacity type vane pump whose delivery rate per rotation decreases as the engine speed increases. The pump is integral with a pump control valve and relief valve.



PS-00259

- (1) Reservoir tank
- (2) Relief valve
- (3) Pump control valve

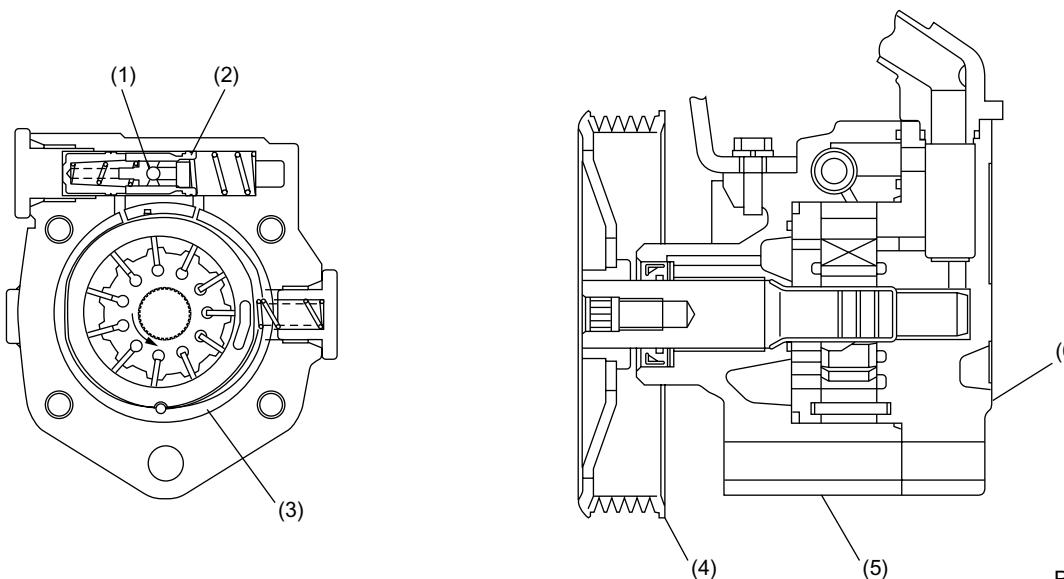
- (4) Vane pump
- (5) Fluid pump assembly
- (6) Steering gearbox

## POWER STEERING SYSTEM

### POWER ASSISTED SYSTEM (POWER STEERING)

- The oil pump is driven by the engine and its flow is controlled in accordance with the engine speed to maintain an adequate steering effort at high speeds.

Also, to improve fuel efficiency and limit temperature rise of the system, a variable displacement vane pump whose output flow per rotation is controlled in accordance with the engine speed is used, and a control valve and a relief valve are built in the pump.



PS-00484

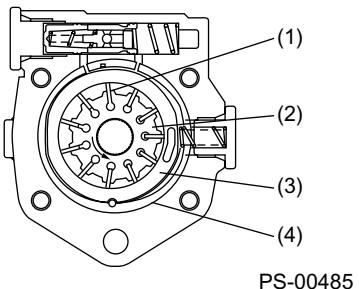
- (1) Relief valve
- (2) Control valve
- (3) Vane pump
- (4) Pulley
- (5) Front body
- (6) Rear body

## POWER STEERING SYSTEM

### POWER ASSISTED SYSTEM (POWER STEERING)

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- The vane pump consists of a rotor, cam ring, adapter, and eleven vanes. When the rotor rotates, the vane in each slot of the rotor is moved out by centrifugal force in radial directions and pressed against the cam ring. The tip of the vanes slide along the inner wall of the cam ring and the oil that has entered the chamber formed by the rotor, cam ring and vanes is discharged continuously.



PS-00485

- (1) Vane
- (2) Rotor
- (3) Cam ring
- (4) Adapter

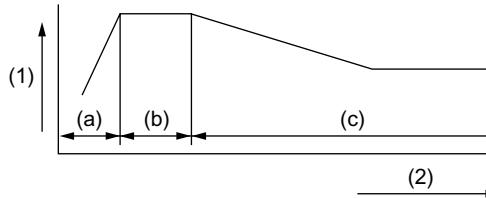
# POWER STEERING SYSTEM

## POWER ASSISTED SYSTEM (POWER STEERING)

- Flow control

Consists of a control valve, orifice, adapter and cam ring, and regulates the amount of oil supplied to the gearbox by changing the eccentricity of the cam ring to control the discharge rate per rotation.

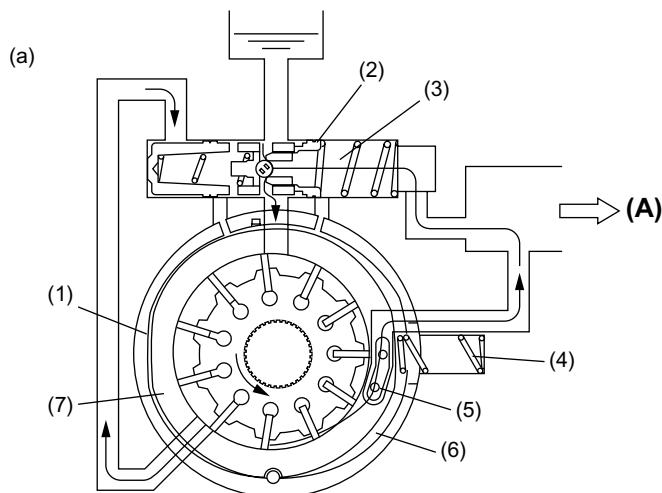
1) In phase (a), the pressure difference is small between both sides of the orifice, and the control valve is pressed to the set position by the control valve spring. Tank pressure is led to pressure chamber A. Pressure after the orifice is led to pressure chamber B. The cam spring is pressed to the set position by the differential pressure between pressure chambers A and B ( $A < B$ ) and the force of the cam spring itself, and maximum discharge rate is achieved.



PS-00486

(1) Discharge flow

(2) Pump speed



PS-00487

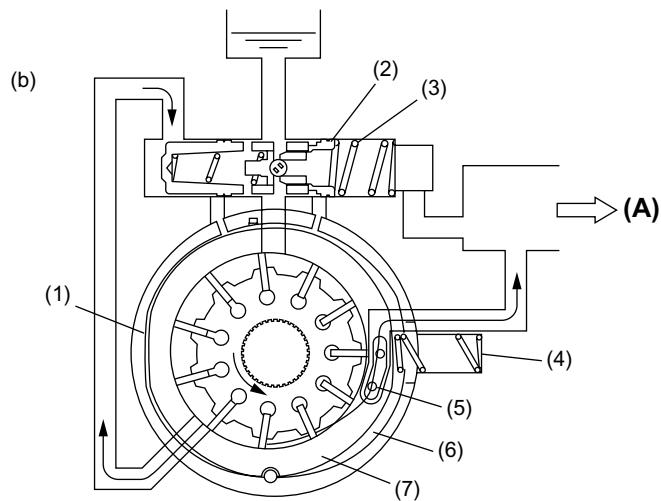
(1) Pressure chamber A  
(2) Control valve  
(3) Control valve spring  
(4) Cam spring

(5) Orifice  
(6) Pressure chamber B  
(7) Cam ring  
(A) To P/S

# POWER STEERING SYSTEM

## POWER ASSISTED SYSTEM (POWER STEERING)

2) In phase (b), the pressure difference between both sides of the orifice increases, and the control valve moves against the valve spring force. Pressure before the orifice is led to pressure chamber A, and the cam ring moves against the cam spring force by the differential pressure between pressure chambers A and B (= differential pressure across the orifice). When the cam spring moves, the delivery rate per rotation decreases and will not increase even when the engine speed increases.



PS-00488

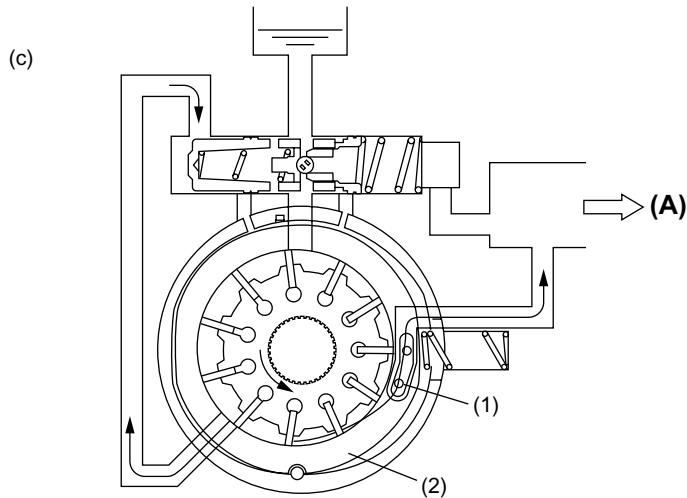
(1) Pressure chamber A  
(2) Control valve  
(3) Control valve spring  
(4) Cam spring

(5) Orifice  
(6) Pressure chamber B  
(7) Cam ring  
(A) To P/S

## POWER STEERING SYSTEM

### POWER ASSISTED SYSTEM (POWER STEERING)

3) In phase (c), the cam spring moves further due to the effect of the orifice, and the flow is controlled as shown in the previous figure.



PS-00489

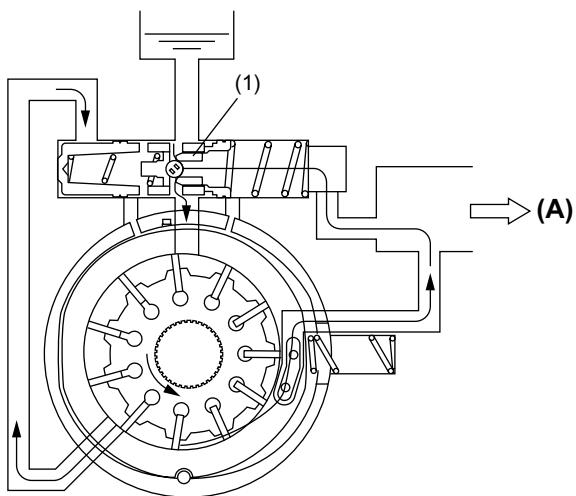
(1) Orifice

(2) Cam ring

(A) To P/S

4) Relief valve operation

When the discharge pressure exceeds the specified value, the relief valve opens to release the discharged oil to the low pressure side and limit the maximum pressure.



PS-00490

(1) Relief valve

(A) To P/S

## **POWER STEERING SYSTEM**

POWER ASSISTED SYSTEM (POWER STEERING)

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**MEMO**