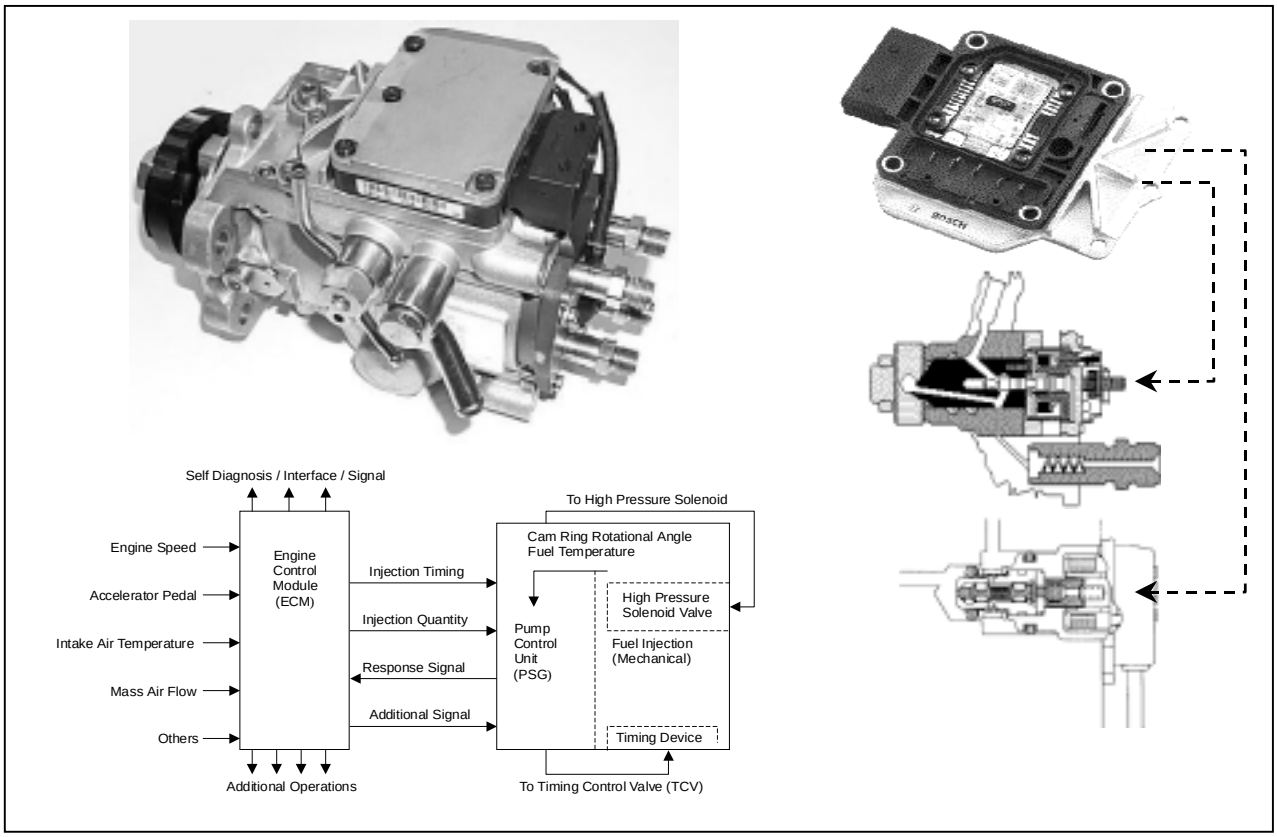
FOR SERVICE TRAINING

BOSCH VP44
FUEL INJECTION SYSTEM

Construction & Operation



Applicable Model

Model Year	*Vehicle Model*	*Engine Model*	*Emission Regulation*
2001 - 2004	*TFR/TFS*	*4JA1-TC / 4JH1-TC*	*Euro 2 / Euro 3*
2001 - 2003	*N*R*	*4JH1-TC*	*Euro 3 / EPA 98*

ISUZU

ISUZU MOTORS LIMITED

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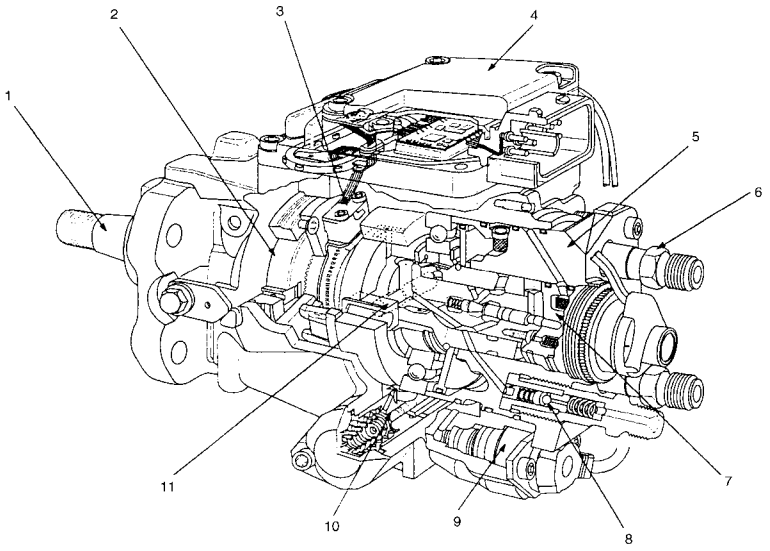
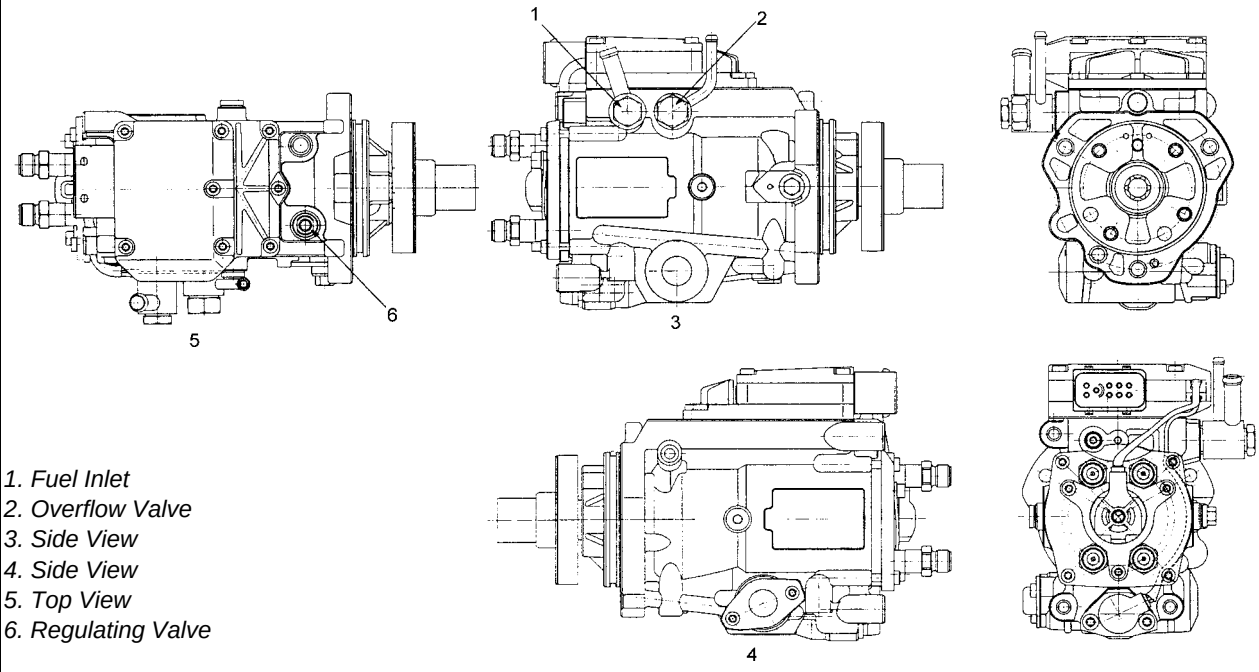
GENERAL INFORMATION



1. Driveshaft
2. Feed Pump
3. Pump Camshaft Speed Sensor
4. Pump Control Unit (PSG)
**PSG=Pumpen Steuer Great (German)*
5. Distributor Head
6. Constant Pressure Valve (CPV) Holder
7. High Pressure Solenoid Valve
8. Constant Pressure Valve (CPV)
9. Timing Control Valve
10. Timer
11. Radial Plunger High Pressure Pump

Instead of the previous face cam type, the radial plunger distributor type injection pump utilizes a cam ring to enable fuel injection at high-pressures, marking it suitable for small, high-speed direct injection diesel engines. This pump was developed to provide the most suitable fuel injection quantity and injection timing to satisfy the demand for engine reliability, derivability, low smoke, low noise, high output and clear exhaust emissions.



1. Fuel Inlet
2. Overflow Valve
3. Side View
4. Side View
5. Top View
6. Regulating Valve

CHARACTERISTIC OF VP44 INJECTION SYSTEM

1. High Pressure Injection
The radial plunger distributor type injection pump is capable of generating pressure of 100 Mpa (approximately 1000 Bar) demanded by small, high speed direct injection diesel engines.

2. High Pressure Atomization of Fuel Injected from the Nozzle
Through high pressure fuel injection, the fuel is atomized at high pressure with a high penetrating force (the fuel droplets penetrate further) and with greater dispersion and distribution (mixing with air is improved) and results in better combustion. This contributes to cleaner emissions.

3. Optimum Fuel Injection
High speed control of fuel injection quantity and fuel injection timing, is performed by the control unit, enabling lower fuel cost and high output.

4. Improved Durability
The components used in the pump are very resistant to high pressure, ensuring improved durability.

5. Improved Engine Matching
As fuel injection is controlled by cylinder selective adaptation, smooth running is improved.

6. Improved Reliability
As a control unit system with both an engine control module (ECM) and a pump control unit (PSG) is used, the control system is extremely reliable.

7. Improved Power Performance
As the control unit controls the optimum fuel injection quantify corresponding to accelerator position, increased torque in low accelerator pedal positions is possible, enabling improved power performance.

8. Decreased Smoke at Acceleration
When the amount of injected fuel is increased, to increase engine power at acceleration, the excess fuel usually generates smoke. The VP44 fuel injection pump, accurately controls fuel injection quantity even in this range to prevent the generation of smoke without adversely affecting acceleration.

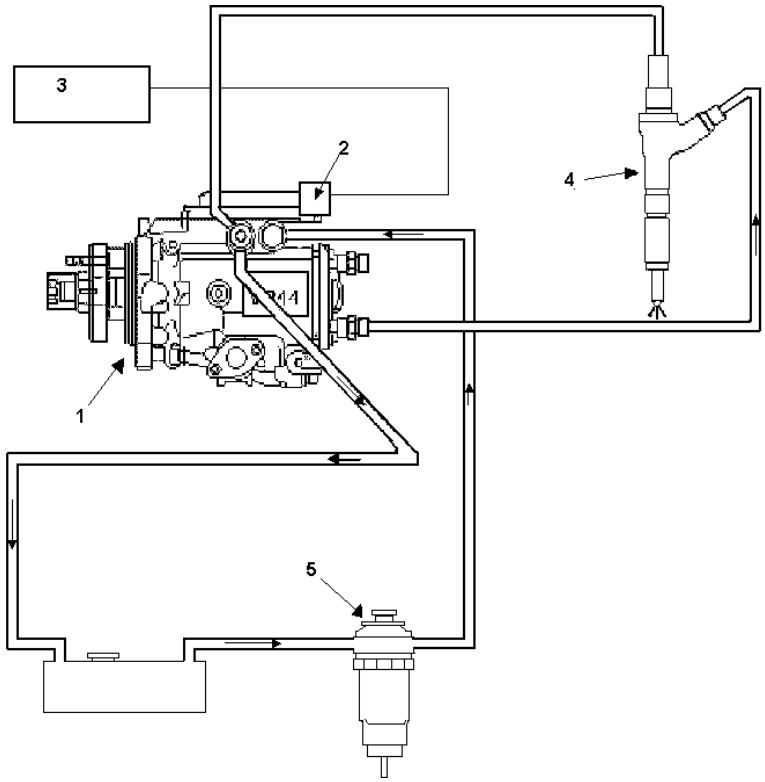
9. Additional Devices are Unnecessary
Such additional devices as the boost compensator and the aneroid compensator are unnecessary, as the control unit compensates, based on signals from each sensor. This results in less "clutter" injection pump.

10. Self Diagnosis Function
The system includes a self-diagnosis function, which displays error codes to facilitate the diagnosis of malfunctions.

VP44 INJECTION PUMP SPECIFICATION

Item	Specification
Injection Pump Type	VP44
Applicable Vehicle	Passenger Vehicle, Recreational Vehicle, Small and Medium Size Truck
Engine Model	4JA1-TC / 4JH1-TC
Applicable Number of Cylinder	4 Cylinder / 6 Cylinder
Direction of Rotation	Clockwise / Counter Clockwise
Drive Method	Toothed Belt/ Gear / Chain
Injection Performance	
Maximum Pump Pressure	100Mpa (Approximately 1000Bar (kgf/cm2))
Plunger Diameter x Number	4 Cylinder: 6.5mm X 2 / 7.0mm X 2 / 7.5mm X 2
Maximum Lift	3.5mm
Maximum Plunger Speed	1.9m/second : 1000rpm
Maximum Allowable Drive Torque	200Nm (20.4kgm): 3 Holed Flange 260Nm (26.5kgm): 4 Holed Flange (Maximum drive torque necessary under actual usage conditions: 150Nm (15.3kgm) limit)
System	
Minimum Drive Voltage	6V
Maximum High Pressure Solenoid	20A
Control Unit Type	Engine Control Module (ECM) / Pump Control Unit (PSG)
Battery Specification	12V / 24V
Standard Performance	
Standard Control Method	Fuel Injection Quantify Control: High Pressure Solenoid Valve, Time Control Injection Timing Control: TCV Duty Solenoid System, Hydraulic Timer
Timing Feed Back	Cam Position Feed Back
Compensation for Fuel Quantity	Pump EPROM, Multi-point Compensation
Timing Advance Angle	Maximum Advanced Angle: 15degrees
Pump Size	Identical to COVEC-F
Weight	Approximately 8.0kg

FUEL SYSTEM



1. VP44 Fuel Injection Pump
2. Injection Pump Control Unit (PSG)
**PSG=Pumpen Steuer Great (German)*
3. Engine Control Unit (ECM)
4. Injection Nozzle
5. Fuel Filter With Water Separator
6. Fuel Tank

1. Fuel Piping System
Surrounding the radial plunger distributor type fuel injection pump, the fuel piping system consists of a fuel tank, a feed pump, a fuel filter, nozzle holder assemblies and piping, connecting these components.

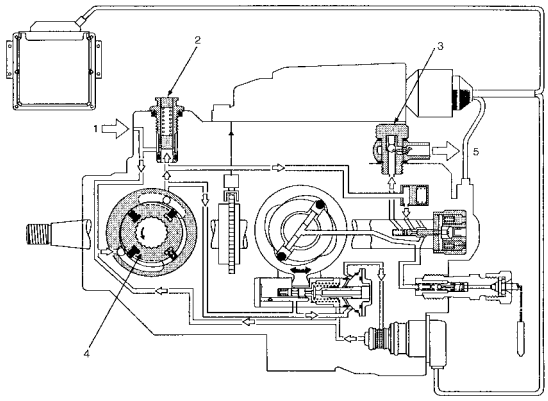
2. Fuel Intake
The fuel in the fuel tank is supplied to the injection pump through the fuel inlet by the internal feed pump in the fuel injection pump, after first passing through the fuel filter. The fuel filter is installed to filter the fuel, and also has a water separator on the bottom to separate any water from the fuel.

3. Regulating Fuel Feed Pressure and Delivery Pressure
The fuel intake in at the fuel intake port is pressurized by the feed pump inside the injection pump, and is then supplied to the plunger chamber through the high pressure solenoid valve's valve needle, which controls the direction of fuel flow.
At this time, the fuel pressure is greatest in proportion to pump rotational speed. When it exceeds a specified pressure, excess fuel is returned to the intake side through the regulating valve.

4. Fuel Pressurization
The fuel delivered to the plunger chamber is pressurized by the radial plungers.

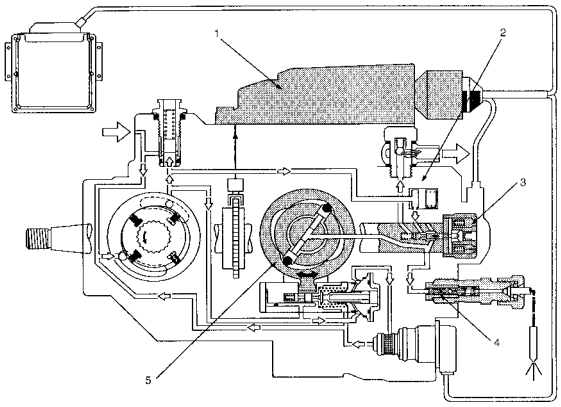
5. Determining the Optimum Fuel Injection Quantity and Fuel Injection Timing
The optimum quantity of high pressure fuel is pressure fed to the nozzle holder assembly at optimum timing by the high pressure solenoid valve and the timing control valve (TCV) controlled by the pump control unit (PSG).

Fuel Intake System



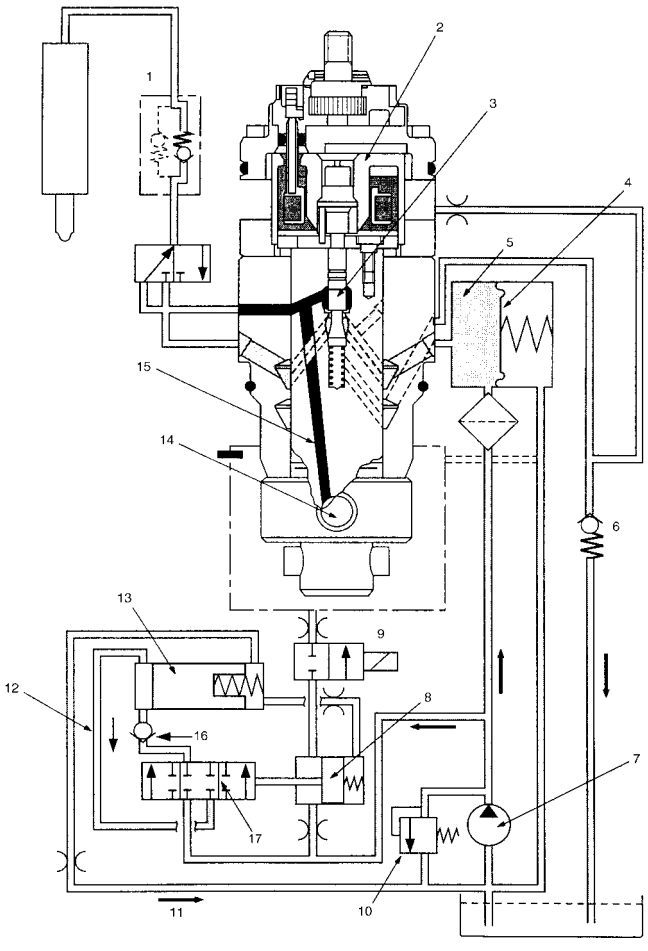
1. Fuel Suction
2. Regulating Valve
3. Overflow Valve
4. Feed Pump
5. To Fuel Tank

Fuel Pressure & Delivery System



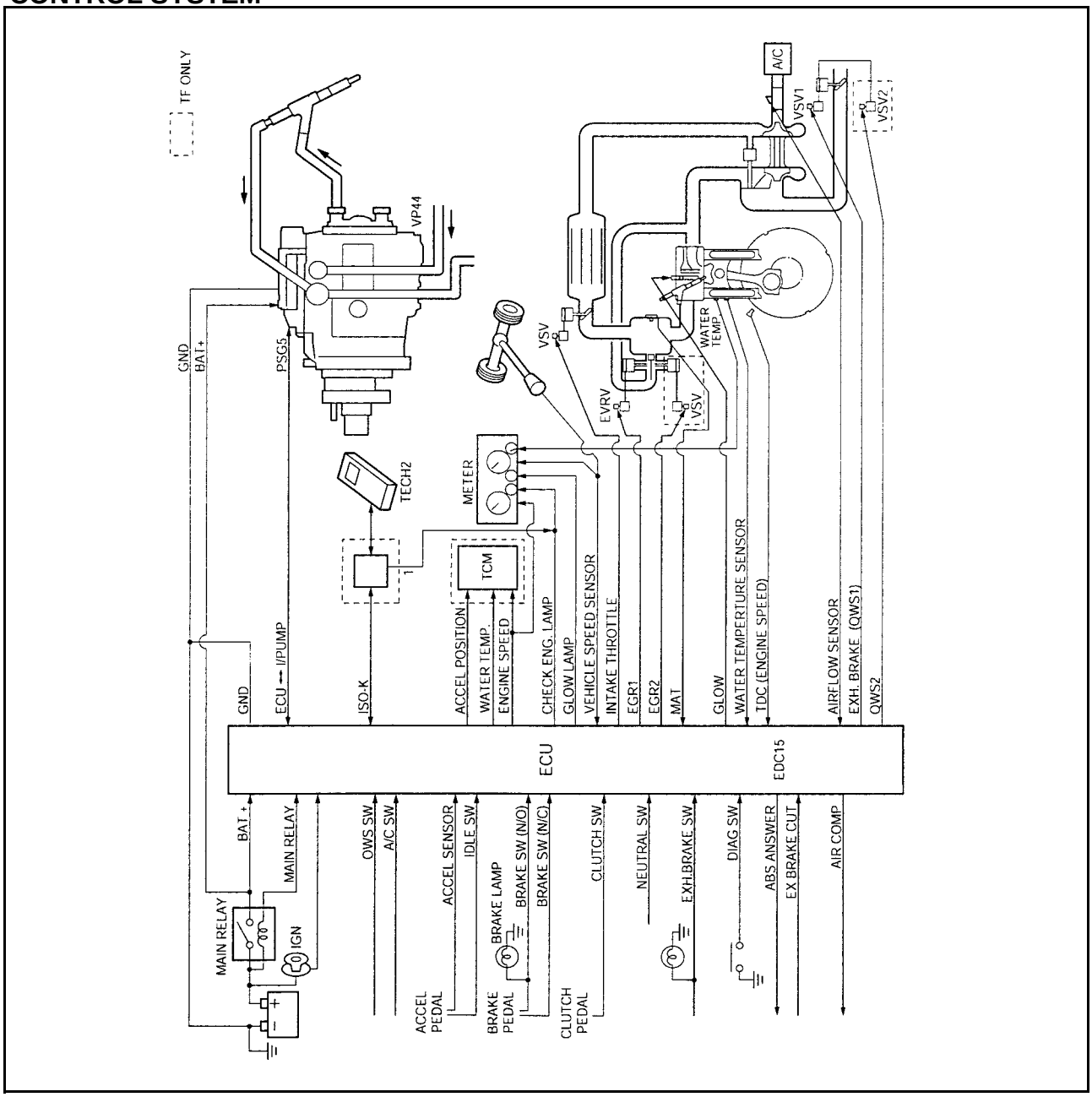
1. Pump Control Unit (PSG)
2. Distributor Head
3. High Pressure Solenoid Valve
4. Constant Pressure Valve (CPV)
5. Radial Plunger High Pressure Pump

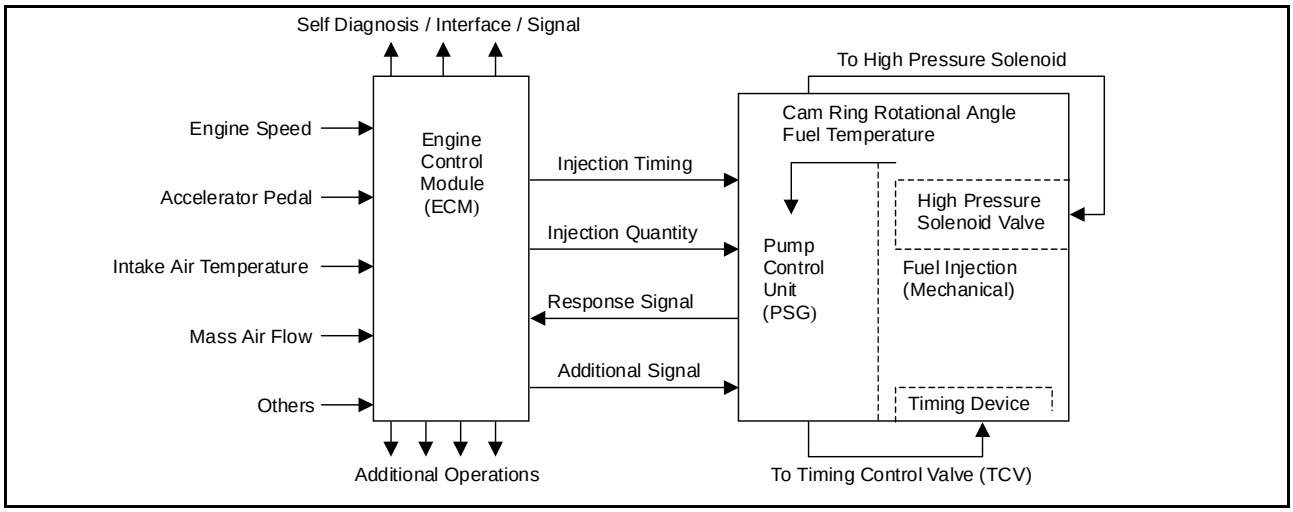
High Pressure Control System



1. Constant Pressure Valve (CPV)
2. High Pressure Solenoid Valve
3. Valve Needle
4. Accumulator Diaphragm
5. Overflow Valve
6. Overflow Valve
7. Feed Pump
8. Hydraulic Stopper
9. Timing Control Valve (TCV)
10. Regulating Valve
11. To Feed Pump Intake
12. Timing Device Fuel Return
13. Timing Piston
14. Radial Plunger
15. High Pressure Passage
16. Timer Piston Fuel Pressure Charge
17. Servo Valve

CONTROL SYSTEM

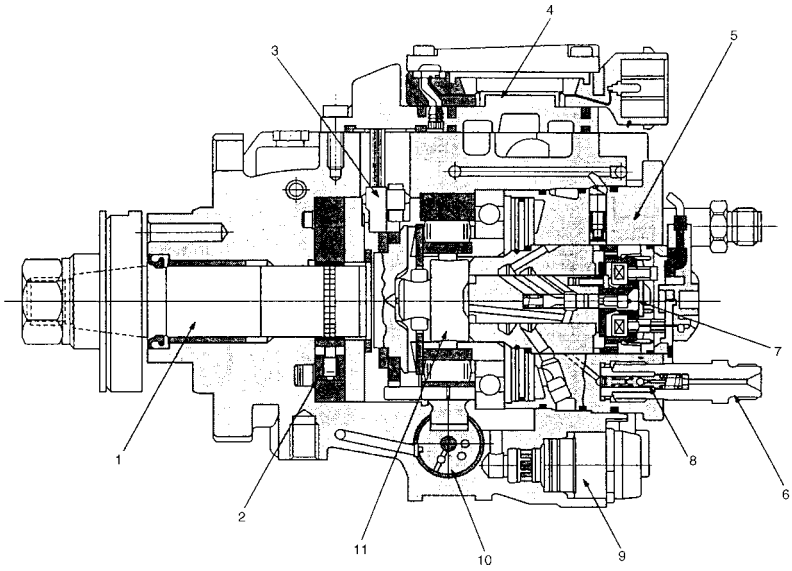




CONSTRUCTION

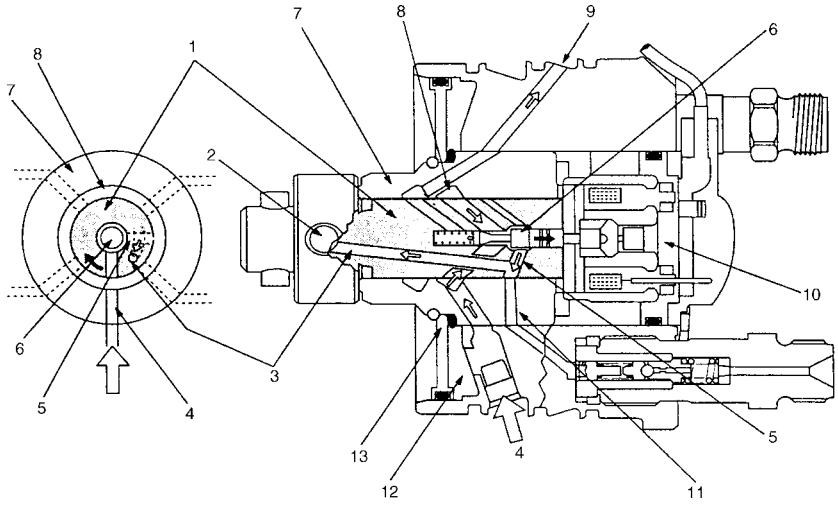
CONSTRUCTION PARTS

Cross Section View

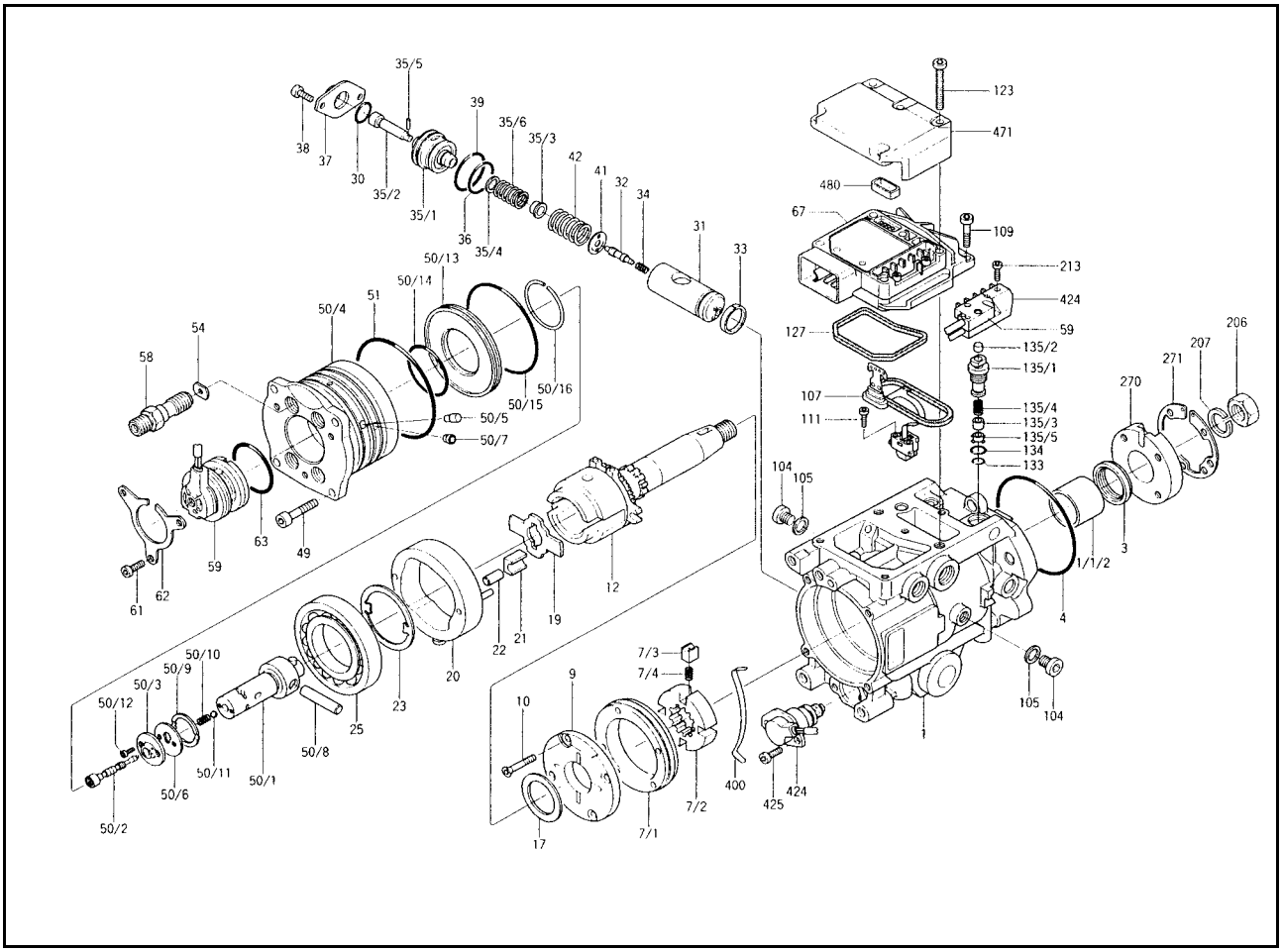


1. Drive Shaft
2. Feed Pump
3. Pump Camshaft Speed Sensor
4. Pump Control Unit (PSG)
5. Distributor Head
6. Constant Pressure Valve (CPV) Holder
7. High Pressure Solenoid Valve
8. Constant Pressure Valve (CPV)
9. Timing Control Valve (TCV)
10 Timer
11. Radial Plunger High Pressure Pump

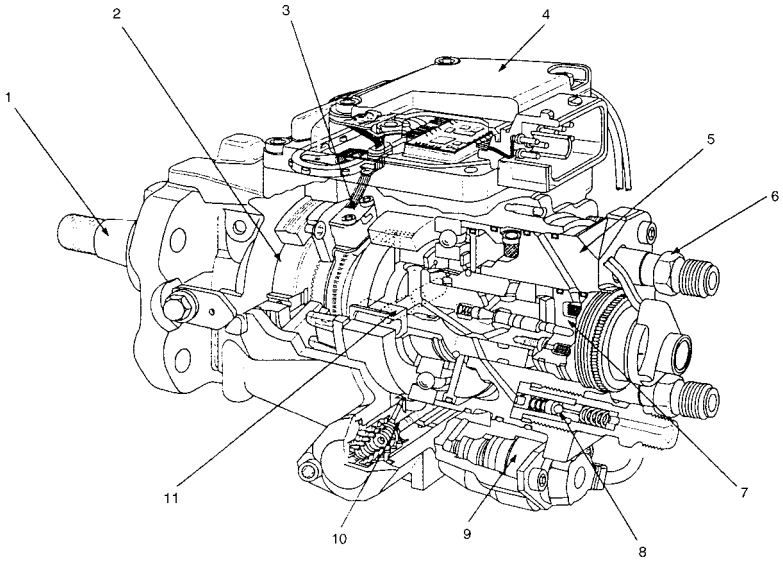
Cross Section View (Distributor Head)



1. Rotor Shaft
2. Radial Plunger
3. High Pressure Passage
4. Low Pressure Inlet
5. Distribution Slit
6. Valve Needle
7. Barrel
8. Annular Passage
9. Fuel Return
10. High Pressure Solenoid Valve
11. High Pressure Outlet
12. Diaphragm Chamber
13. Accumulator Diaphragm



INJECTION PUMP MAIN BODY CONSTRUCTION



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**PSG=Pumpen Steuer Great (German)*
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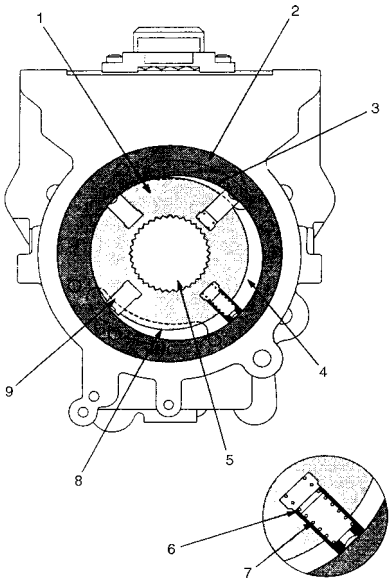
8. Constant Pressure Valve (CPV)
9. Timing Control Valve
10. Timer
11. Radial Plunger High Pressure Pump

FEED PUMP

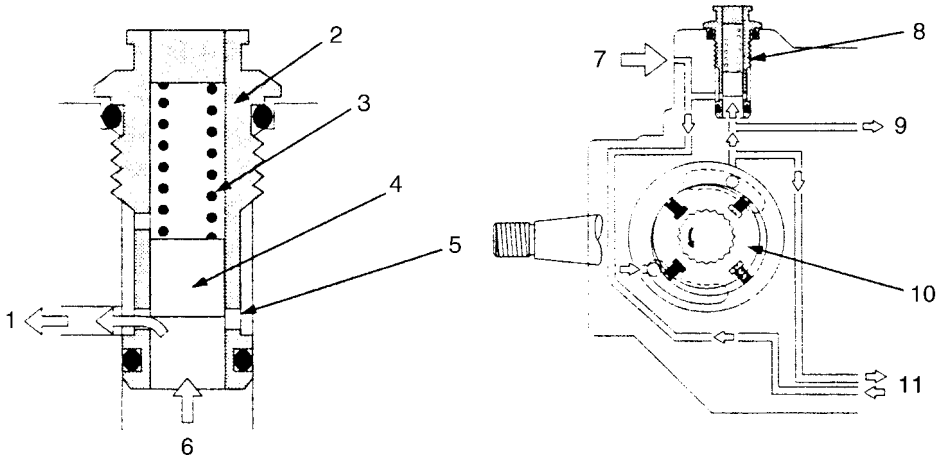
1. Rotor
2. Casing Ring
3. Outlet
4. Chamber
5. Drive Shaft
6. Vane
7. Spring
8. Inlet
9. Vane



The feed pump consists of a rotor, vanes and a casing ring. The rotor is driven by the drive shaft. Four vanes are assembled in the rotor.
A spring is assembled on the inside of each vane, and each vane is always pushed against the casing by this spring force and centrifugal force.
When the rotor is driven by the drive shaft, the volume of the inlet side chamber increases and fuel from the fuel tank is sucked in through the inlet.
Conversely, the volume of the outlet side chamber decreases and fuel is delivered to the radial plunger high pressure pump through a regulating valve, which maintain the fuel delivery pressure from the outlet at a pressure thereby not exceeding a specified pressure.

REGULATING VALVE

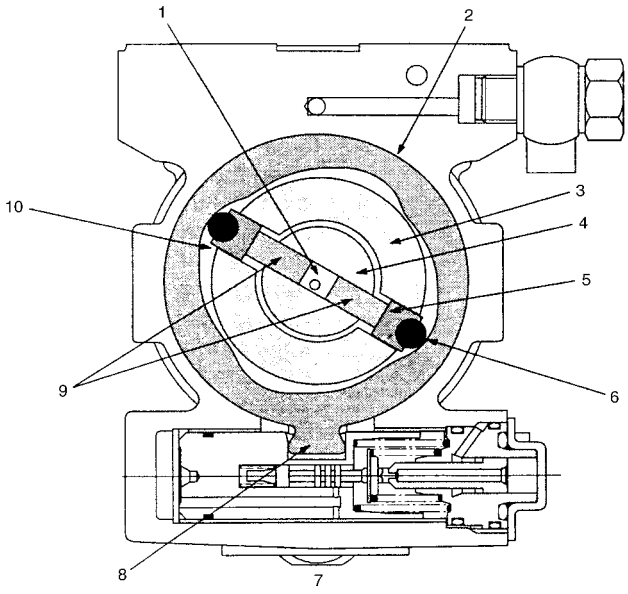
1. To Inlet
2. Valve Holder
3. Spring
4. Valve Piston
5. Port
6. From Outlet
7. Fuel Intake
8. Regulating Valve
9. To Radial Plunger High Pressure Pump
10. Feed Pump
11. Timing Device



The regulating valve consists of a valve holder, a spring and a valve piston. The ports in the valve holder are arranged in a radial manner.
The valve piston is pushed to block the ports by the spring force.

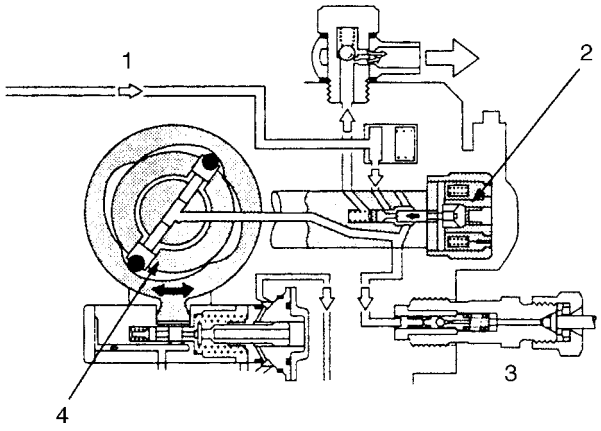
RADIAL PLUNGER HIGH PRESSURE PUMP (HIGH PRESSURE SECTION)

1. Plunger Chamber
2. Cam Ring
3. Drive Shaft
4. Rotor Shaft
5. Roller Shoe
6. Roller
7. Timing Device
8. Ball Pin
9. Radial Plungers
10. Drive Shaft Guide Slit



The high pressure pump consists of a cam ring, a rotor shaft, roller supports, rollers and plungers. The cam ring has cams on the inner race (4 cylinder 4 cams) and the cam ring is connected to the timing devise by a ball pin.
The rotor is driven by a fuse plate, which is connected to the rotor shaft.
The radial plungers are pushed against the cam ring by fuel pressure delivered by fuel feed pump. With drive shaft rotation, the radial plungers are pushed inwards the center of the rotor shaft by the cams on the cam ring to compress the fuel.

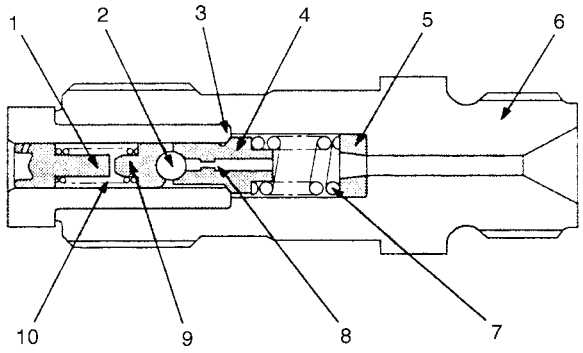
1. From Feed Pump
2. High Pressure Solenoid Valve
3. Constant Pressure Valve (CPV) Holder
4. Radial Plunger High Pressure Pump



The filling of the high pressure pump, and the compression of fuel in the high pressure pump, is controlled by the high pressure solenoid valve.

CONSTANT PRESSURE VALVE (CPV)

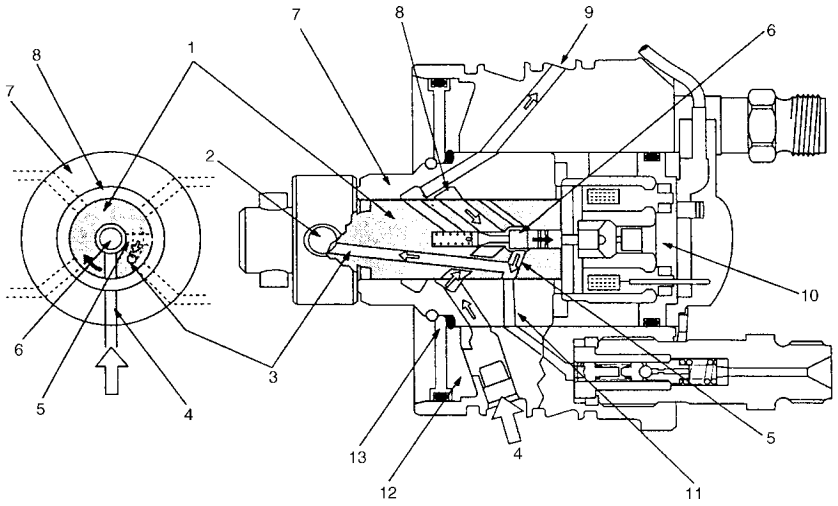
1. Plug
2. Ball
3. Seat
4. Valve
5. Spacer
6. Holder
7. Valve Spring
8. Orifice
9. Ball Support
10. Spring



The constant pressure valve (CPV) consists of a holder, a spacer, a valve spring, a valve, a seat, a ball, a ball support, a spring and a plug.
The valve is equipped with an orifice to suppress the reflected pressure wave (the cause of secondary injection) caused by nozzle closing at the end of the injection.
The valve is opened by pressurized fuel and this high pressure fuel is delivered to the nozzle holder assembly.

DISTRIBUTOR HEAD

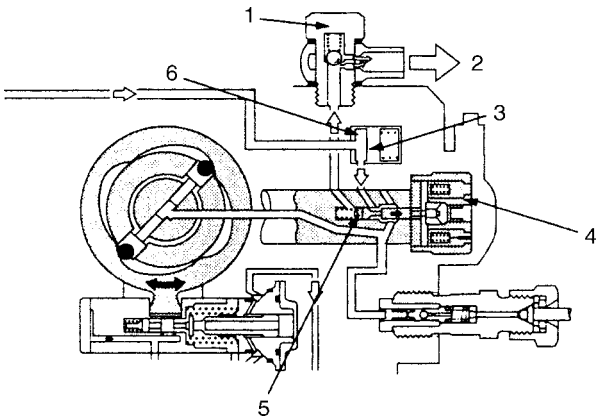
1. Rotor Shaft
2. Radial Plunger
3. High Pressure Passage
4. Low Pressure Inlet
5. Distribution Slit
6. Valve Needle
7. Barrel
8. Annular Passage
9. Fuel Return
10. High Pressure Solenoid Valve
11. High Pressure Outlet
12. Diaphragm Chamber
13. Accumulator Diaphragm



The distributor head consists of a head, a barrel press fitted to the head, a rotor shaft, which slides inside the barrel, a high pressure solenoid valve needle and an accumulator diaphragm.
The fuel supplied by the feed pump flows through the low pressure inlet, the accumulator diaphragm chamber and an annular passage.
During the fuel suction process, the high pressure solenoid valve's valve needle seat is open (current supply OFF) and the high pressure passage is filled with fuel.
The fuel pressure (low pressure) pushes the radial plungers outward (towards the cam ring), and excess fuel returns to the fuel tank through the fuel return and the overflow valve.
During the fuel pressure delivery process, the high pressure solenoid valve seat is closed (current supply ON).
As a result of the rotor rotation the fuel is compressed by the radial plungers, and flows through the distributor slits connected to the high pressure outlets and to the nozzle holder assembly via the constant pressure valve (CPV) holder.
At the end of the injection, the high pressure solenoid valve current is turned OFF and the valve needle seat is opened, even though plunger movement continues until the radial plunger reaches the cam's top dead center.

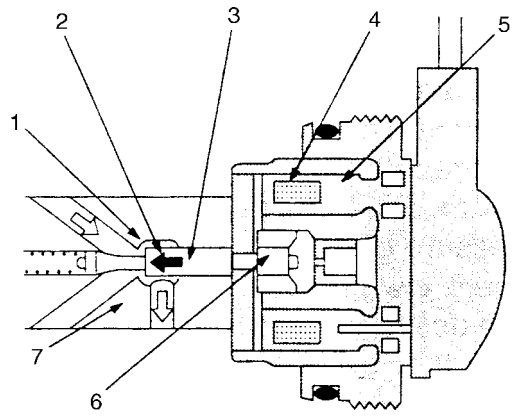
After the completion of pressure delivery, the excess fuel flows through the passage to the diaphragm chamber, where pressure is decreased by the accumulator diaphragm and, simultaneously, accumulated for the next injection.

1. Overflow Valve
2. To Fuel Tank
3. Accumulator Diaphragm
4. High Pressure Solenoid Valve
5. Valve Needle
6. Diaphragm Chamber



HIGH PRESSURE SOLENOID VALVE

1. Valve Seat
2. Valve Closing Direction
3. Valve Needle
4. Coil
5. Magnet
6. Magnet Anchor
7. Rotor Shaft



The high pressure solenoid valve consists of a valve seat, a valve needle, and a magnet anchor (a movable iron core), a coil and a magnet. The valve needle rotates together with the rotor shaft.

When current controlled by the pump control unit (PSG) flows to the coil, the magnet anchor and the valve needle are pushed towards the valve seat.

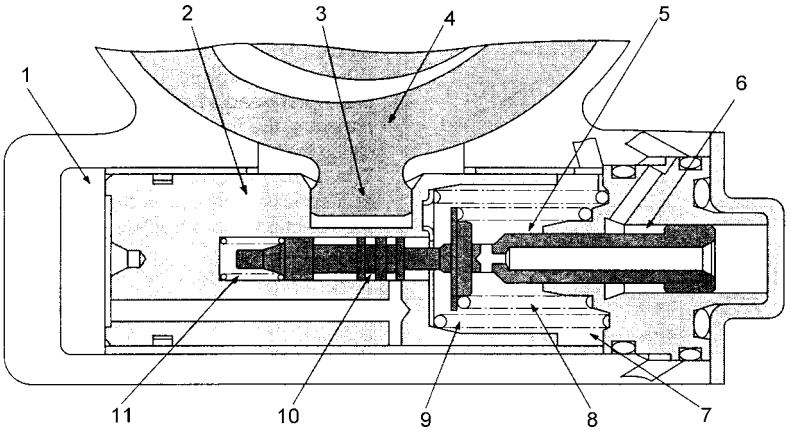
When the valve seat is completely closed by the valve needle, the fuel in the high pressure passage is isolated from the low pressure passage, is compressed by the radial plunger high pressure pump, and injected into the engine cylinder through the nozzle holder assembly.

When the required injection quantity is reached, the current to the coil is cut, the valve seat opens and injection of fuel is completed.

The high pressure solenoid valve determines the supply of fuel to the radial plunger high pressure pump and the injection quantity for each cylinder.

TIMING DEVICE

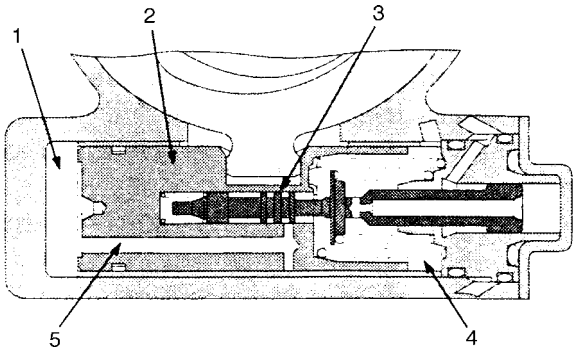
1. Timing Piston High Pressure Chamber
2. Timing Piston
3. Ball
4. Cam Ring
5. Hydraulic Stopper
6. Annular Chamber
7. Timing Piston Low Pressure Chamber
8. Hydraulic Stopper Return Spring
9. Timing Piston Return Spring
10. Servo Valve
11. Servo Valve Set Spring



The timing device consists of a timing device plunger, a servo valve set spring, a hydraulic stopper, a hydraulic stopper return spring and a timing device plunger return spring.
The timing device is installed on the bottom of the pump housing perpendicular to the injection pump's axial orientation.
The timing plunger is connected to the ball of the cam ring so that axial movement of the timing plunger is coveted to cam ring rotation.

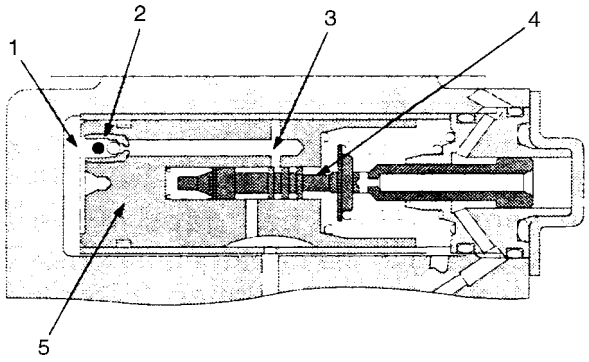
The timing plunger contains a servo valve, which opens and closes a control port, a hydraulic stopper, which acting in the same axial direction, sets the position of the servo valve, and a return spring.
On the left of the timer piston is the timer piston drive pressure chamber (a high pressure chamber), and on the right is the timer's low pressure chamber. The delivery pressure of the fuel delivered from the feed pump acts on the annular chamber, which is connected to the timing control valve (TCV).

1. Timing Piston High Pressure Chamber
2. Timing Piston
3. Servo Valve
4. Low Pressure Chamber
5. Return Channel



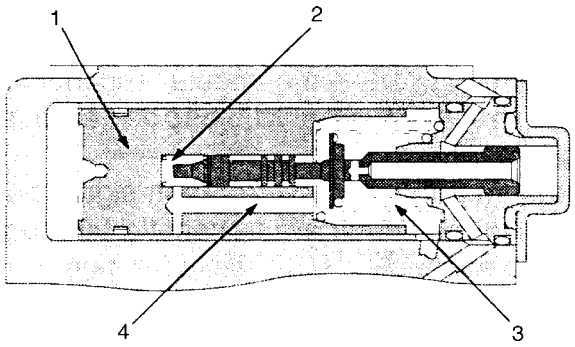
Above figure is side view of the timing device.
The timer piston has a return channel connecting the high pressure chamber to the low pressure chamber via the servo valve. (This is the return passage for fuel with the timing plunger in retarded position.)

1. Timing Piston High Pressure Chamber
2. Check Valve
3. Inlet Channel
4. Servo Valve
5. Timing Piston



Above figure is top view of the timing device.
The timing plunger has a inlet channel connecting the high pressure chamber and the feed pump's outlet side passage through the servo valve. (This is the fuel passage when the timing plunger is in advance position.)
The inlet channel is equipped with a check valve (with a ball valve on the orifice side, and a pin press fitted on the opposite) to prevent reverse flow from the high pressure chamber to the feed pump.

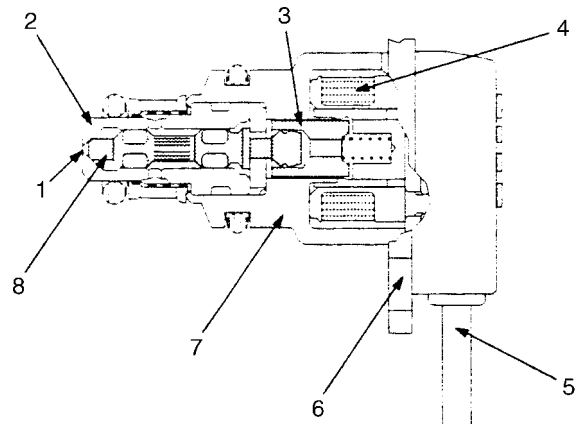
1. Timing Piston
2. Servo Valve Set Spring Chamber
3. Low Pressure Chamber
4. Spring Chamber Pressure Balance Port



Above figure is side view of the timing device.
The timing plunger has a spring chamber balance port connecting the servo valve set spring chamber and the low pressure chamber. (This passage equalizes the pressure of the servo valve set spring chamber.)

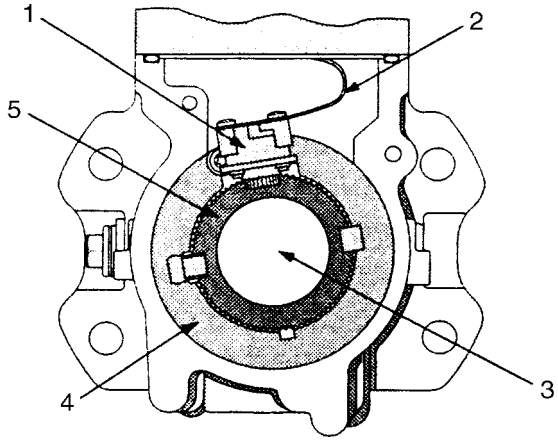
TIMING CONTROL VALVE (TCV)

1. Orifice Port
2. Valve Body
3. Magnet Anchor
4. Coil
5. Connector
6. Flange Plate For Installation
7. Valve Casing
8. Valve Needle



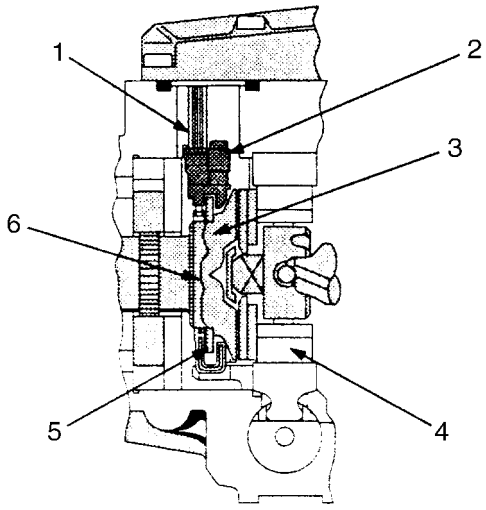
The timing control valve (TCV) consists of a valve body, a valve needle, a valve casing, a magnet anchor (a movable iron core), a coil, a flange plate and a connector.
The valve body equipped with an orifice port.
The timing control valve (TCV) is installed on the pump housing and controls the pressure of the annular chamber of the timer's hydraulic stopper.

PUMP CAMSHAFT SPEED SENSOR



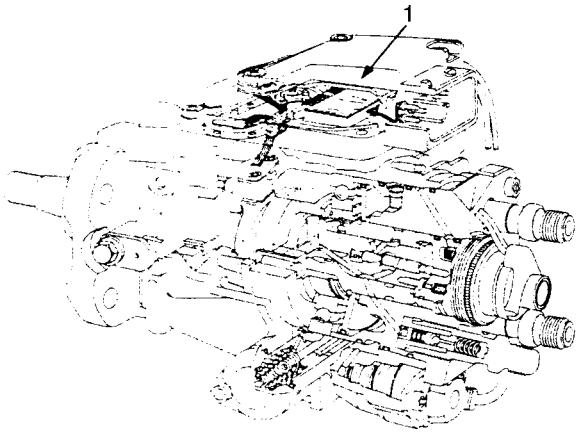
1. Pump Camshaft Speed Sensor
2. Flexible Connecting Harness
3. Drive Shaft
4. Pump Camshaft Peed Sensor Retaining Ring
5. Sensor Wheel

The pump camshaft speed sensor consists of a flexible connecting harness, the pump camshaft speed sensor itself, and the pump camshaft speed sensor retaining ring.
A sensor wheel with precisely machined teeth is fixed to the drive shaft.
The sensor wheel has gaps in teeth corresponding to the cylinder positions. These gaps are in a fixed relation to the engine cylinders and the camshaft.
The teeth are scanned by the pump camshaft speed sensor to determine the actual speed of the injection pump.
The pump camshaft speed sensor is mounted on the retaining ring, which can be rotated and is connected to the cam ring. Thus, the sensor ring rotates with the cam ring in response to timer movement.
The cam ring's angular signal and the actual pump speed are transmitted through the flexible connecting harness to the pump control unit (PSG).



1. Flexible Connecting Harness
2. Pump Camshaft Speed Sensor
3. Drive Shaft
4. Cam Ring
5. Sensor Wheel
6. Pump Camshaft Speed Sensor Retaining Ring

PUMP CONTROL UNIT (PSG)



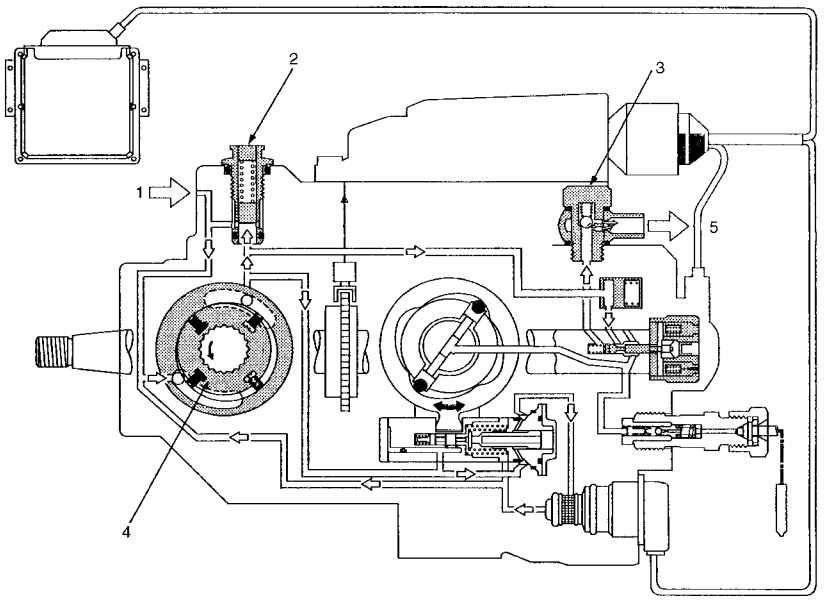
1. Pump Control Unit (PSG)

The pump control unit (PSG) is installed directly on top of the injection pump and is equipped with a temperature sensor.
The pump control unit (PSG) determines the control signals for the timing control valve (TCV) and high pressure solenoid valve depending on information given by the engine control module (ECM).

The pump control unit (PSG) receives signals from the pump camshaft speed sensor for injection pump speed and cam ring rotation and sends out timing control valve (TCV) control signals which are the basic timing drive signal values.
Fuel injection quantities are predetermined in the engine control module (ECM) and are converted into drive signals for the high pressure solenoid valve.
This enables the pump control unit (PSG) to control the injection duration time. At this time, fuel temperature is taken into consideration.
The fuel in the injection pump cools the bottom of the pump control unit (PSG).

LOW PRESSURE FUEL CIRCUIT

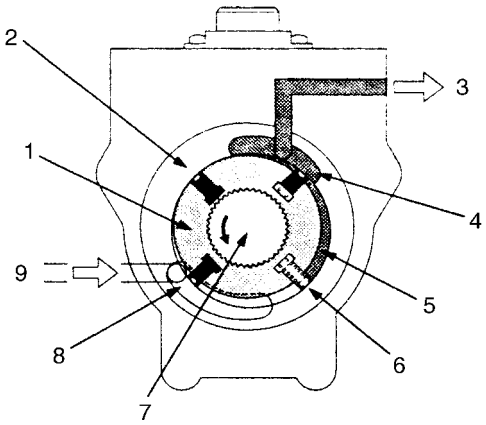
CONSTRUCTION PARTS



1. Fuel Suction
2. Regulating Valve
3. Overflow Valve
4. Feed Pump
5. To Fuel Tank

The low pressure fuel circuit must supply sufficient fuel to the high pressure fuel circuit. The main components are the feed pump, the regulating valve and the overflow valve.

FEED PUMP

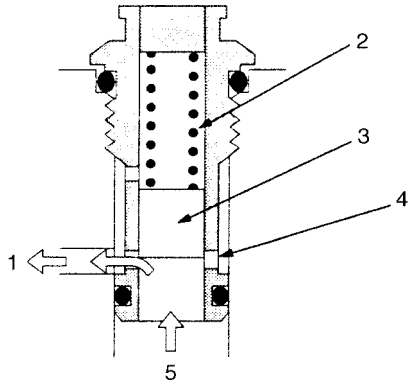


1. Rotor
2. Casing Ring
3. Fuel Supply
4. Outlet
5. Chamber
6. Vane
7. Drive Shaft
8. Inlet
9. Fuel Suction

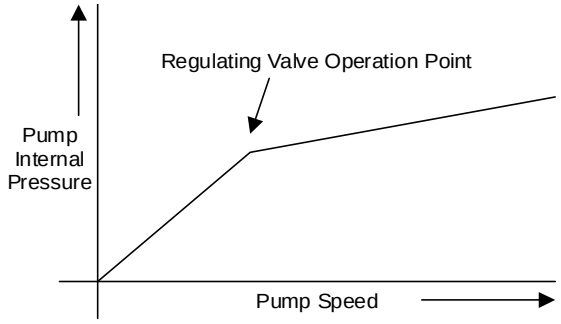
The feed pump, driven by the drive shaft, performs suction and supply of fuel.
The vanes assembled in the rotor are pressed against the inside of the casing ring by spring forces and centrifugal force during rotation to form chambers.
When the vanes rotate, the volume of these chambers increase when they reach recesses the casing ring connected to the inlet port. Pressure then decreases and fuel is drawn in.
When the chambers have passed the inlets and recesses, the volume decreases and the fuel is compressed. Fuel pressure increases until the chamber reaches the outlet, where the fuel passes through the regulating valve to the high pressure fuel circuit.

REGULATING VALVE

1. To Inlet
2. Valve Holder
3. Spring
4. Valve Piston
5. Port
6. From Outlet

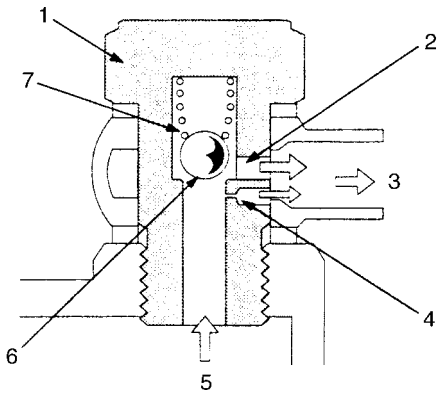


When feed pump speed increases so that the delivery pressure of the fuel delivered from the outlet exceeds the regulating valve spring force, the plunger is pushed upwards.
Excess fuel passes through the ports and returns to the inlet side, and the delivery pressure is maintained within a specified range.
When feed pump speed decreases so that the delivery pressure decreases, the plunger is pushed downwards by spring force to close the port.



OVERFLOW VALVE

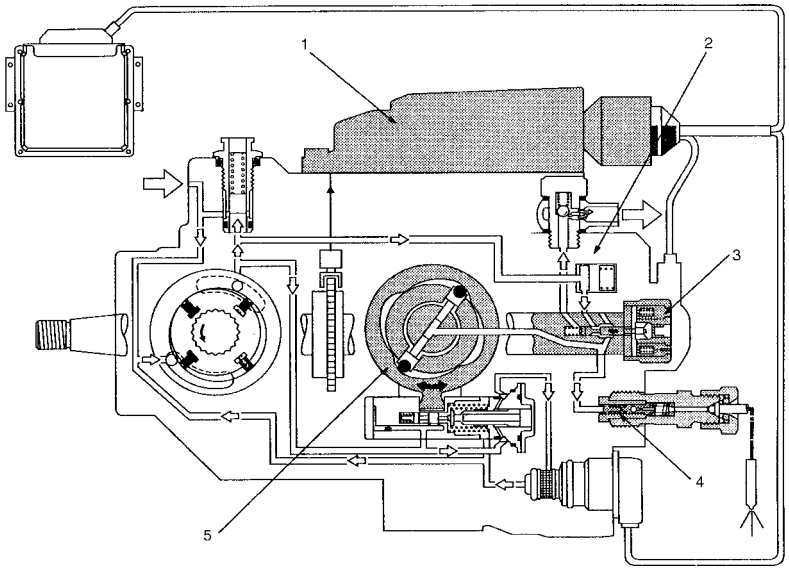
1. Valve Holder
2. Port
3. To Fuel Tank
4. Orifice Port
5. From Fuel Tank
6. Ball Valve
7. Spring



When the pressure of the fuel, returned from the distributor head, exceeds the spring force, the overflow valve's ball valve is pushed up.
Excess fuel presses through the port and returns to the tank, and fuel pressure inside the pump chamber does not exceed a specified pressure.
The flow of excess fuel serves cooling and automatic bleeding of the fuel pump during operation. Also the orifice port is installed to assist in automatic air bleeding.

HIGH PRESSURE FUEL CIRCUIT

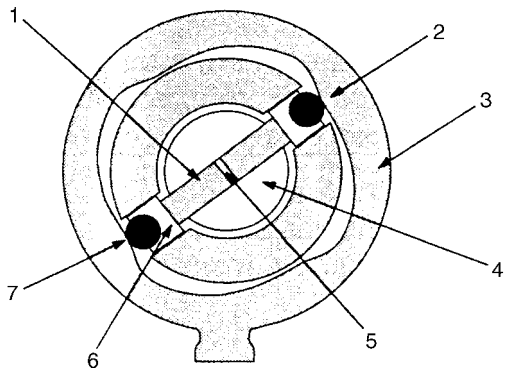
CONSTRUCTION PARTS



1. Pump Control Unit (PSG)
2. Distributor Head
3. High Pressure Solenoid Valve
4. Constant Pressure Valve (CPV)
5. Radial Plunger High Pressure Pump

In addition high pressure generating device, the high pressure circuit also consists of fuel piping, and devices to set the beginning of injection and fuel injection quantity.
The main components are as follows.
High pressure generation: **Radial Plunger High Pressure Pump**
Fuel distribution: **Distributor Head**
Beginning of injection timing: **Timing Device**
Prevention of secondary injection: **Constant Pressure Valve (CPV)**

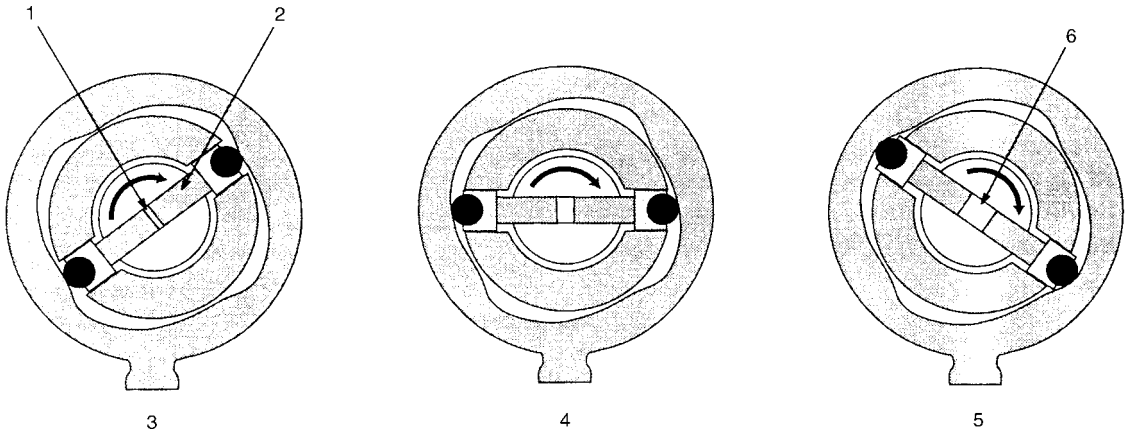
RADIAL PLUNGER HIGH PRESSURE PUMP



1. Radial Plunger
2. Internal Cam
3. Cam Ring
4. Rotor Shaft
5. Plunger Chamber
6. Roller Shoe
7. Roller

While the radial plungers assembled to the rotor shaft rotate, they are held against the inside of the cam ring (via the roller shoes and rollers) by fuel delivery pressure from the feed pump and centrifugal force.
The radial plungers perform rotational movement as well as internal cam induced reciprocating movement to suck in and compress the fuel in the plunger chamber.

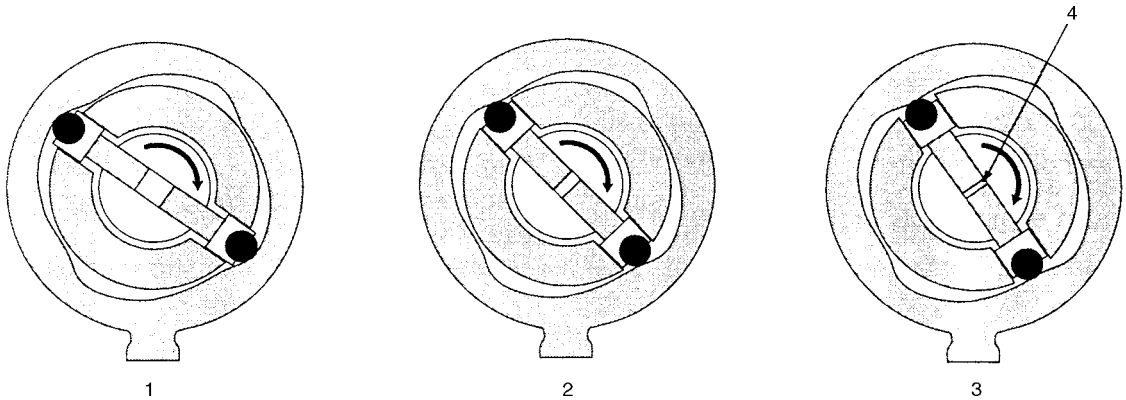
1. Fuel Suction



1. Plunger Chamber
2. Radial Plunger
3. Radial Plunger Top Dead Center
4. Radial Plunger Intermediate
5. Radial Plunger Bottom Dead Center
6. Fuel Suction

When the radial plungers rotate from the top dead center position, the volume of the plunger chamber increases.
The plunger chamber is filled with fuel, as a result of the internal pump pressure. During this period the high pressure solenoid is open. (and the high pressure passage from the feed pump is open.)

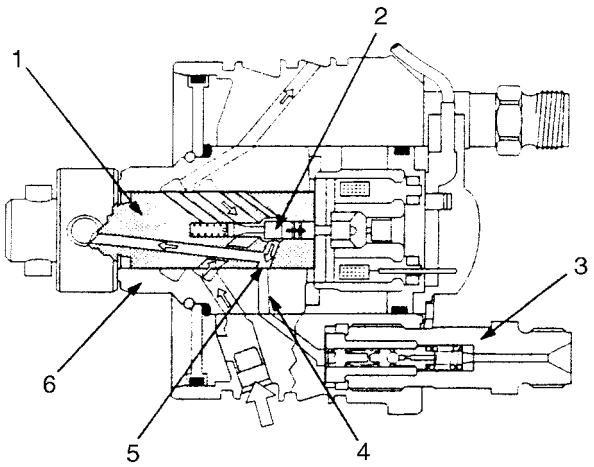
2. Fuel Compression



1. Radial Plunger Bottom Dead Center
2. Radial Plunger Intermediate
3. Radial Plunger Top Dead Center
4. Fuel Compression

When the radial plungers rotate from the bottom dead center, they are pressed inward by the cam ring's internal cams so that the volume of the plunger camber decreases, and fuel is compressed until the plungers reach the top dead center.
During fuel injection, the high pressure solenoid valve's valve needle seat is closed (and the high pressure passage from the feed pump is closed).

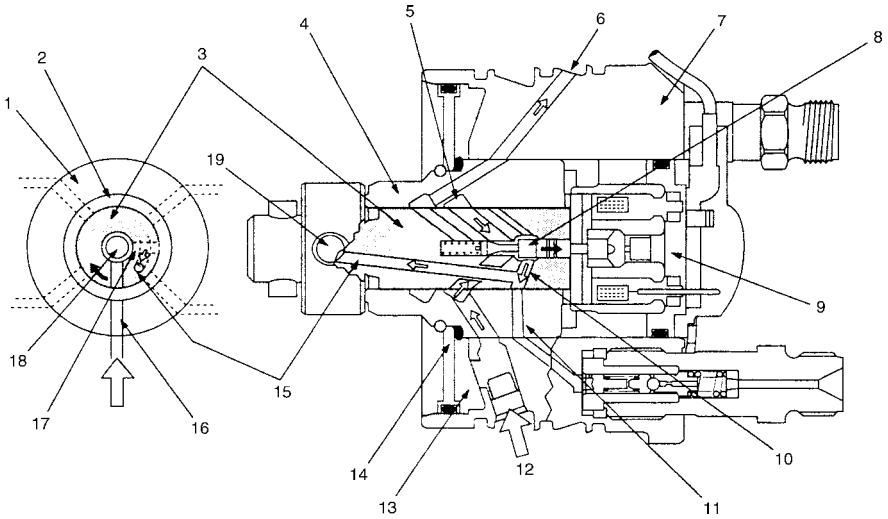
DISTRIBUTOR HEAD



1. Rotor Shaft
2. Valve Needle
3. Constant Pressure Valve (CPV) Holder
4. High Pressure Outlet
5. Distributor Shaft
6. Barrel

The distributor head distribute the high pressure fuel that has flowed through the rotating rotor shaft's distributor slits and the barrel's high pressure outlets (4 cylinders: 4) to the engine cylinders via the constant pressure valve (CPV) and the nozzle holder assemblies.
The high pressure solenoid valve needle changes the passage to the radial plunger high pressure pump between fuel suction and fuel compression.

1. Fuel Suction Process

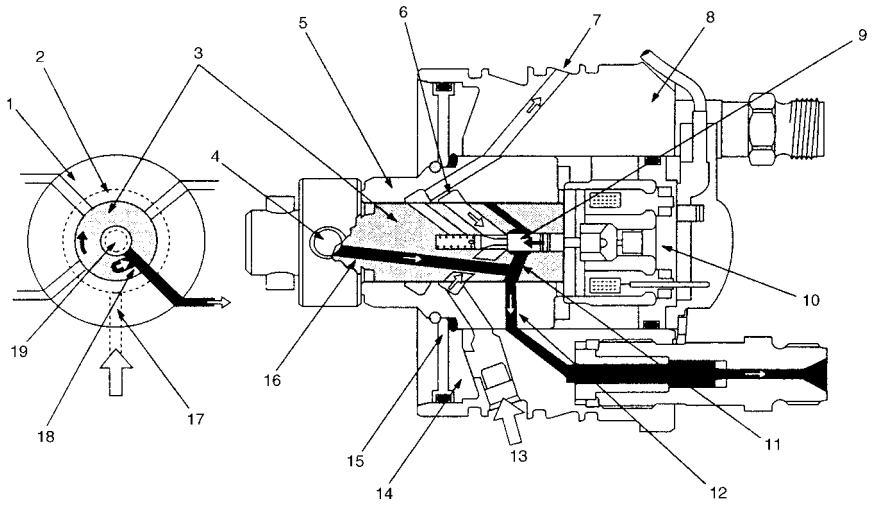


1. Barrel
2. Annular Passage
3. Rotor Shaft
4. Radial Plunger
5. Annular Passage
6. Fuel Return
7. Head
8. Valve Needle
9. High Pressure Solenoid Valve
10. Distributor Slit
11. High Pressure Outlet
12. Low Pressure Inlet
13. Diaphragm Chamber
14. Accumulator Diaphragm
15. High Pressure Passage
16. Low Pressure Inlet
17. Distributor Slit
18. Valve Needle
19. Radial Plunger

When the plungers move in the bottom dead center direction from the top dead center, the fuel delivered from the feed pump flows from the low pressure inlet, through the annular passage and the valve needle into the distributor head, and is delivered into the high pressure passage.
The radial plungers are pushed against the cam ring's inner cams by the fuel delivery pressure, the volume of the plunger chamber increases, and fuel suction is performed.
At this time, the rotor shaft's distributor slits are not connected to the barrel's high pressure outlets.

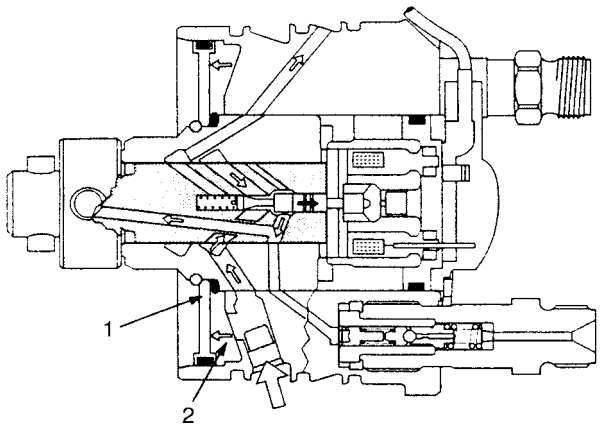
2. Fuel Pressure Delivery Process

1. Barrel
2. Annular Passage
3. Rotor Shaft
4. Radial Plunger
5. Barrel
6. Annular Plunger
7. Fuel Return
8. Head
9. Valve Needle
10. High Pressure Solenoid Valve
11. Distributor Slit
12. High Pressure Outlet
13. Low Pressure Inlet
14. Diaphragm Chamber
15. Accumulator Diaphragm
16. High Pressure Passage
17. Low Pressure Inlet
18. Distributor Slit
19. Valve Needle



The cam ring pushes the radial plungers inwards, decreasing the volume of the plunger chamber and the fuel is compressed.
At this time, the distributor slits are connected to the barrel's high pressure outlets by rotor shaft rotation.
The high pressure fuel is then delivered through the high pressure passage, the distributor slits and the high pressure outlets, and then through the constant pressure valve (CPV) to the nozzle holder assemblies.

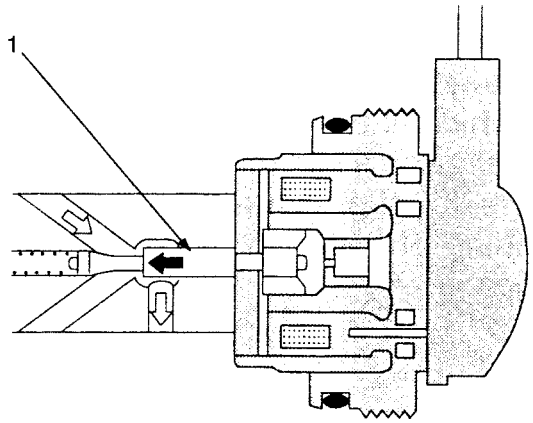
3. End of Fuel Pressure Delivery



1. Accumulator Diaphragm
2. Diaphragm Chamber

Fuel injection quantity control is performed from the beginning of pressure delivery at the beginning of cam lift until the high pressure solenoid valve opens at the end of pressure delivery.
This interval is called the pressure delivery interval. Accordingly, the interval that the high pressure solenoid valve is closed determines the fuel injection quantity (high pressure fuel supply ends when the high pressure solenoid valve opens).
Even after the high pressure solenoid valve's end of pressure delivery (high pressure solenoid valve: open), the radial plungers continue to pressurize fuel until they reach the cam's top dead center.
The excess fuel flows through the passage until it reaches the diaphragm chamber. At this time, the accumulator diaphragm decreases the pressure of the fuel flowing back to the low pressure circuit. At the same time fuel is accumulated in preparation for the next injection.

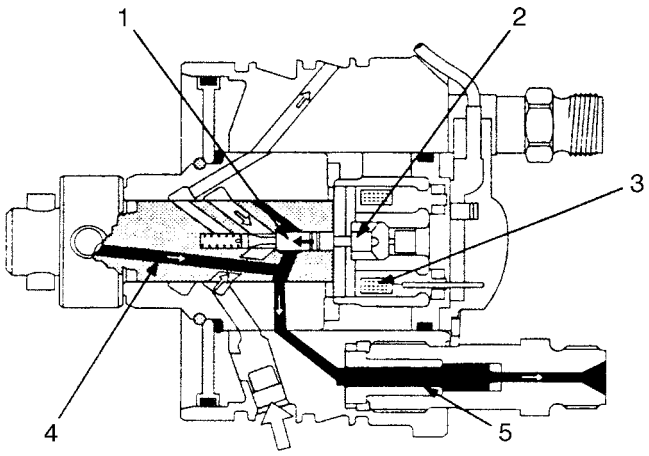
HIGH PRESSURE SOLENOID VALVE



1. Valve Needle

The high pressure solenoid valve has a valve needle, which is opened and closed by control current from the pump control unit (PSG).
This results is opening and closing of the outflow passage to control fuel injection quantity.

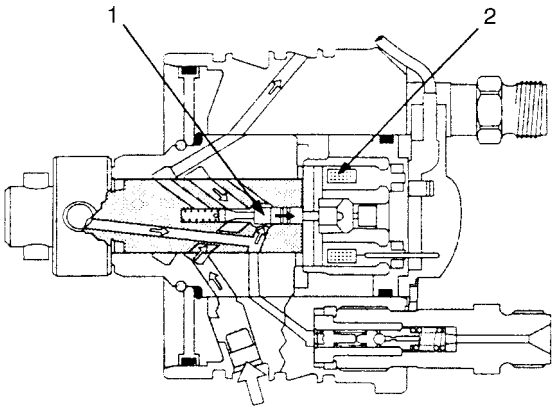
1. Beginning of Fuel Injection



1. Valve Needle
2. Magnet Anchor
3. Coil
4. High Pressure Passage
5. Constant Pressure Valve (CPV)

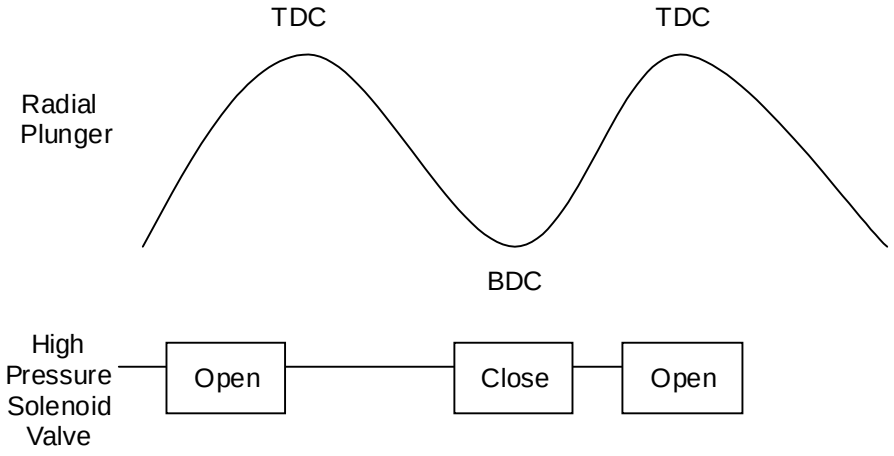
When current from the pump control unit (PSG) flows to the high pressure solenoid valve coil, the magnet anchor (a movable iron core) pushes the valve needle, toward the valve seat.
When the valve seat is completely closed by the valve needle, the way, of the fuel in the high pressure passage to the low pressure circuit is closed.
The pressure of the fuel in the high pressure passage is rapidly increased by radial plunger lift, and the high pressure fuel is delivered through the constant pressure valve (CPV) to the nozzle holder assembly and is injected into the engine cylinder.

2. End of Injection



1. Valve Needle
2. Coil

When the fuel injection quantity demanded by the engine is reached, the current to the coil is cut and the valve needle re-opens the valve seat.
As a result of this, a path is opened for the fuel in the high pressure passage to the low pressure circuit and the pressure decreases. With a decrease in injection pressure the nozzle closes and injection ends.
To accurately control this process, the pump control unit (PSG) determines the actual closing point of the high pressure solenoid valve.

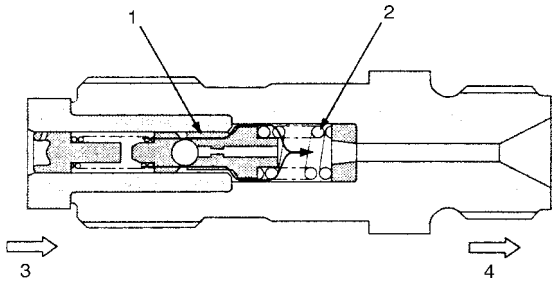


CONSTANT PRESSURE VALVE (CPV)

The constant pressure valve (CPV) decreases the reverse pressure waves (reflected wave) generated at nozzle valve closing to prevent the nozzle from re-opening (secondary injection).
Also, the constant pressure valve (CPV) suppresses the generation of cavitation in the high pressure pipe, which is the cause of pipe erosion, and maintains a stable pressure in the injection pipe (residual pressure) to ensure stabilized injection timing for subsequent injection.

1. Beginning of Delivery

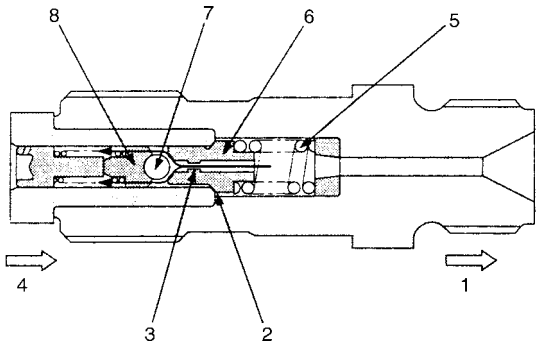
1. Valve
2. Valve Spring
3. From High Pressure Passage
4. To Nozzle Holder



The radial plunger compresses the fuel in the plunger chamber. When the pressure of the fuel delivered to the constant pressure valve (CPV) overcomes the residual pressure in the injection pipe and the valve spring set force, the valve is pushed up and the fuel is delivered to the nozzle holder assembly (beginning of fuel delivery).

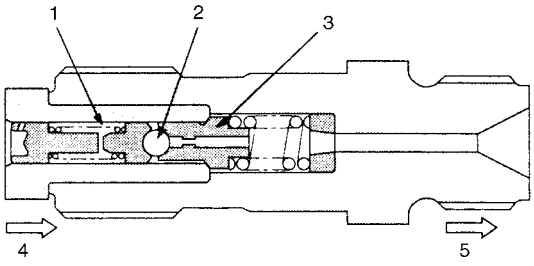
2. End of Injection

1. To Nozzle Holder
2. Seat
3. Orifice
4. From High Pressure Passage
5. Valve Spring
6. Valve
7. Ball
8. Ball Support



When the opening of the high pressure solenoid valve suddenly decreases the pressure in the high pressure passage, the valve is pushed against the seat by the valve spring set force and closes.
At this time, the reverse pressure waves (reflected wave) generated by nozzle closing flows through the orifice, pushes down the ball and ball support and are decreased.

1. Spring
2. Ball
3. Valve
4. From High Pressure Passage
5. To Nozzle Holder

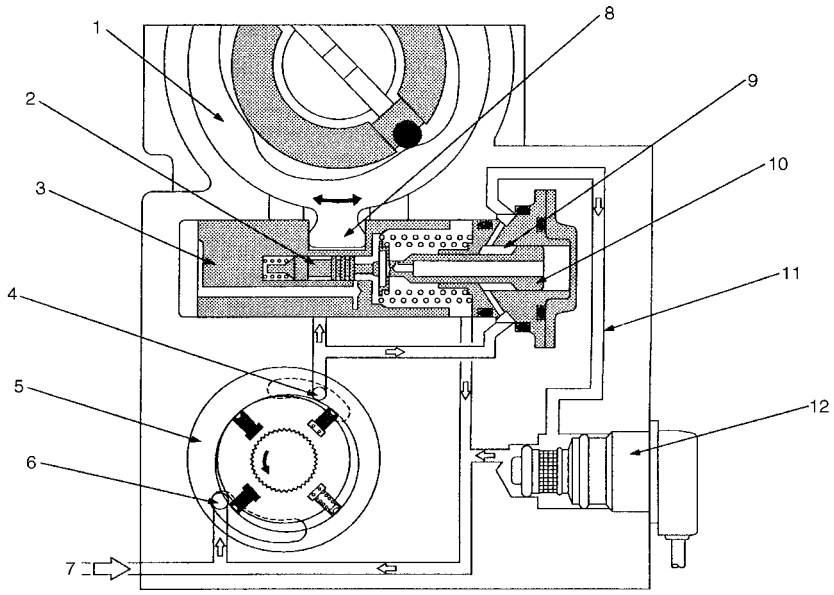


When the pressure of the fuel in the pipe falls below a specified pressure, the ball is pushed against the valve by the spring to prevent the return of fuel inside the pipe.
As a result of this, a stable pressure is maintained in the pipe (residual pressure) until the next delivery interval.

TIMING CONTROL

TIMER OPERATION

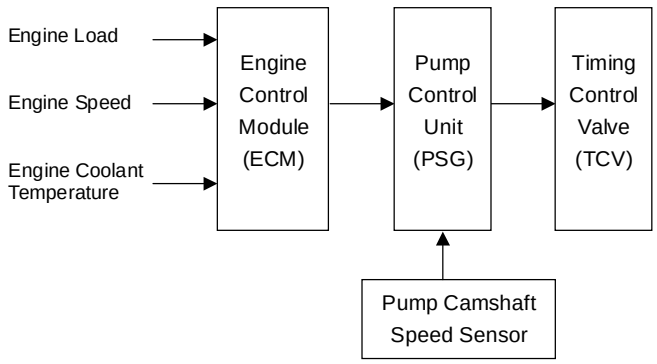
1. Cam Ring
2. Servo Valve
3. Timer Piston
4. Outlet
5. Feed Pump
6. Inlet
7. Fuel Suction
8. Ball Pin
9. Annular Chamber
10. Hydraulic Stopper
11. Return Passage
12. Timing Control Valve (TCV)



The timing device determines the optimum injection timing against variations in engine speed.
The pressure of the fuel fed from the feed pump is adjusted in accordance with speed by the regulating valve. This delivery pressure acts on the hydraulic stopper's annular chamber as control pressure.

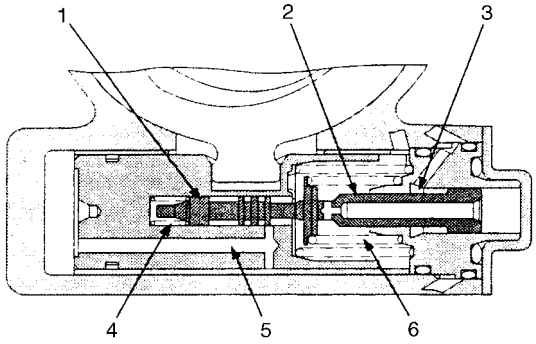
The chamber pressure of the annular chamber is controlled by the timing control valve (TCV).
The timing plunger is connected to the cam ring by a ball pin. Axial movement of the timing plunger is transferred to the cam ring in the form of rotational movement. Movement to the right of the timing plunger (to the spring side) advances injection timing.
The main components are timing plunger, the timing control valve (TCV) and pump camshaft position sensor.

1. Beginning of Injection Setting



The engine control module (ECM) contains characteristic maps of the beginning of injection, corresponding to engine operating conditions (engine load, engine speed and engine coolant temperature).
The pump control unit (PSG) is constantly comparing the set beginning of injection timing and the actual beginning of injection timing.
If there is a difference, the timing control valve (TCV) is controlled by the duty ratio. (The actual beginning of injection timing is determined from the pump camshaft speed sensor.)

2. When the Annular Chamber Pressure is Low (Advance Angle 0)



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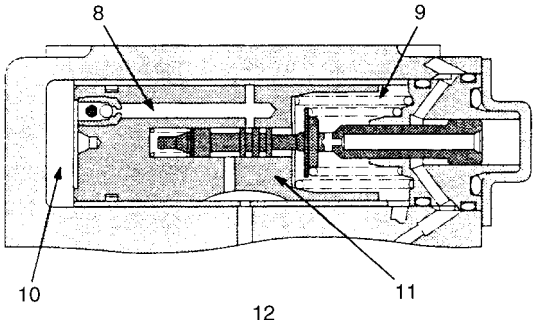
1. Servo Valve
2. Hydraulic Stopper
3. Annular Chamber
4. Servo Valve Set Spring
5. Return Channel
6. Hydraulic Stopper Return Spring
7. Side View of Timing Device
8. Inlet Channel
9. Timing Piston Return Spring
10. High Pressure Chamber
11. Timing Piston
12. Top View of Timing Device



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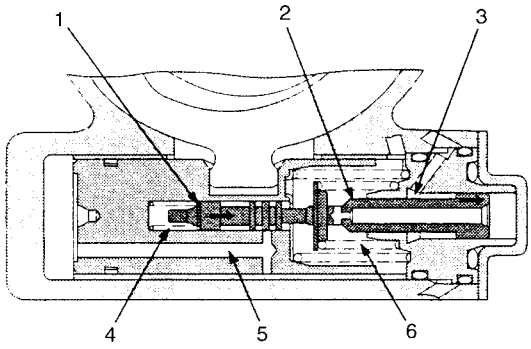
When the pressure of the annular chamber is less than the set force of the hydraulic stopper's return spring, the hydraulic stopper is pushed to the left (in the retard direction).
Consequently, the servo valve is also pushed to the left and stops at the position where it balances the force of the servo valve set spring.
Because of this, the passage to the timer's high pressure chamber (inlet channel) is cut.
The timer piston is held on the left hand side (retard side) by the timer piston return spring.
Return Channel: **Open**
Inlet Channel: **Close**

3. When the Annular Chamber Pressure has Increased (Advance)

1. Servo Valve
2. Hydraulic Stopper
3. Annular Chamber
4. Servo Valve Set Spring
5. Return Channel
6. Hydraulic Stopper Return Spring
7. Side View of Timing Device
8. Inlet Channel
9. Timing Piston Return Spring
10. High Pressure Chamber
11. Timing Piston
12. Top View of Timing Device



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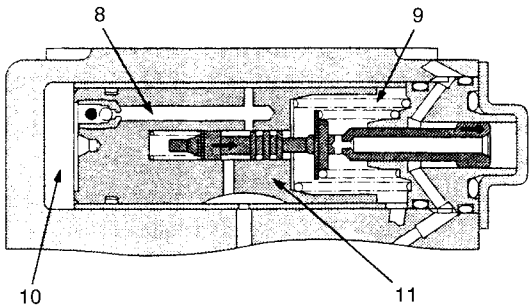

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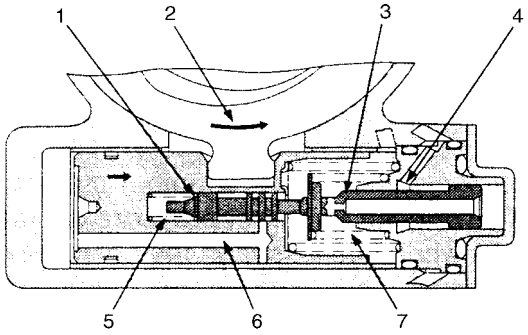
When the annular chamber pressure increases and exceeds the force of the hydraulic stopper return spring, the hydraulic stopper is moved to the right (in the advance direction).
Consequently, the servo valve is also moved to the right by the servo valve set spring and the inlet cannel to the timer's high pressure chamber is opened.
Return Channel: **Open**
Inlet Channel: **Open**

1. Servo Valve
2. Cam Ring
3. Hydraulic Stopper
4. Annular Chamber
5. Servo Valve Set Spring
6. Return Channel
7. Hydraulic Stopper Return Spring
8. Side View of Timing Device
9. Inlet Channel
10. Timer Piston Return Spring
11. High Pressure Chamber
12. From Feed Pump
13. Timing Piston
14. Top of View of Timing Device



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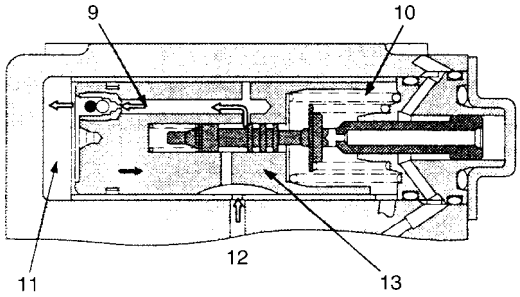
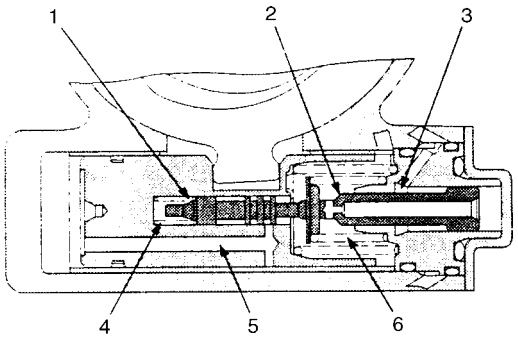


14

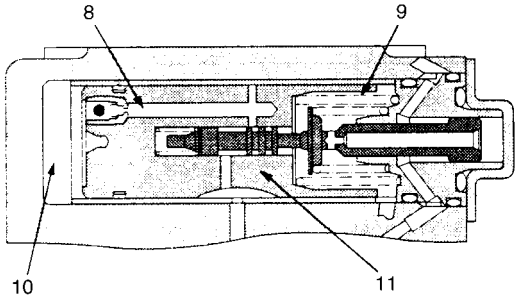
The fuel from the feed pump flows through the inlet channel into the timer's high pressure chamber. When the fuel feed pressure exceeds the set force of the timer piston's return spring, the timer piston is pushed to the right (in the advance direction) and the cam ring is turned in the advance direction. Consequently, the cam ring's cams advance the radial plunger's beginning of compression interval to bring about an advance in the injection beginning of injection.
A maximum timer advance angle position of 15 cam angle degrees (equivalent to 30 crankshaft degrees) is possible.
Return Channel: **Close**
Inlet Channel: **Open**

4. Stable Condition



7

1. Servo Valve
2. Hydraulic Stopper
3. Annular Chamber
4. Servo Valve Set Spring
5. Return Channel
6. Hydraulic Stopper Return Spring
7. Side View of Timing Device
8. Inlet Channel
9. Timing Piston Return Spring
10. High Pressure Chamber
11. Timing Piston
12. Top View of Timing Device

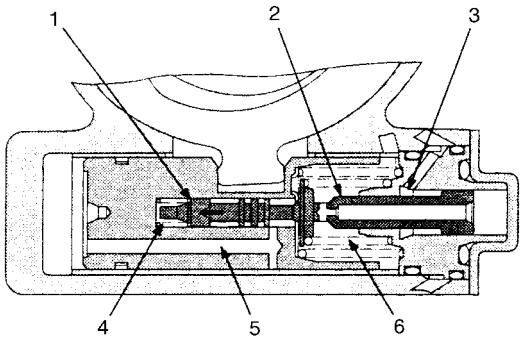


12

The hydraulic stopper is moved to the right, the annular chamber pressure and the set force of the hydraulic stopper return spring are balanced, and the hydraulic stopper is stationary.
The timer piston, imitating servo valve movement, is moved in a direction to cut the inlet channel. Consequently, the flow of fuel to the timer's high pressure chamber is stopped, and the timer piston stops in the position where the timer's high pressure chamber pressure and the set force of the timer piston return spring are balanced.
Return Channel: **Close**
Inlet Channel: **Close**

5. Annular Chamber Pressure has Decreased (Retard)

1. Servo Valve
2. Hydraulic Stopper
3. Annular Chamber
4. Servo Valve Set Spring
5. Return Channel
6. Hydraulic Stopper Return Spring
7. Side View of Timing Device
8. Inlet Channel
9. Timing Piston Return Spring
10. High Pressure Chamber
11. Timing Piston
12. Low Pressure Chamber
13. Top View of Timing Device



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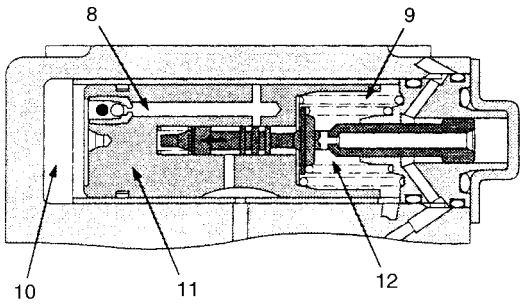
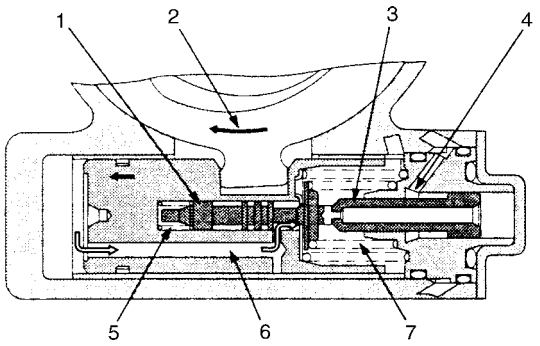


13

The timing control valve (TCV), in response to pump control unit (PSG) control signals, increases the time that the return passage (between the annular chamber and the feed pump inlet) is open to decrease annular chamber pressure.
The annular chamber pressure decreases. When it is less than the set force of the hydraulic stopper return spring, the hydraulic stopper and the servo valve move to the left (in the retard direction).
This happens until the set forces of the hydraulic stopper spring and servo valve set spring are in balance with the annular chamber pressure.
Consequently, the return channel connecting the timing high pressure chamber to the low pressure chamber is opened.
Return Channel: **Open**
Inlet Channel: **Close**

1. Servo Valve
2. Cam Ring
3. Hydraulic Stopper
4. Annular Chamber
5. Servo Valve Set Spring
6. Return Channel
7. Hydraulic Stopper Return Spring
8. Side View of Timing Device
9. Inlet Channel
10. Timing Piston Return Spring
11. High Pressure Chamber
12. Timing Piston
13. Low Pressure Chamber
14. Top View of Timing Device



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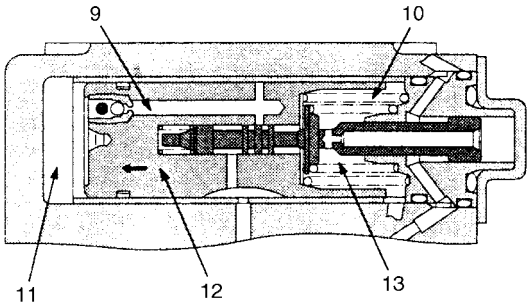


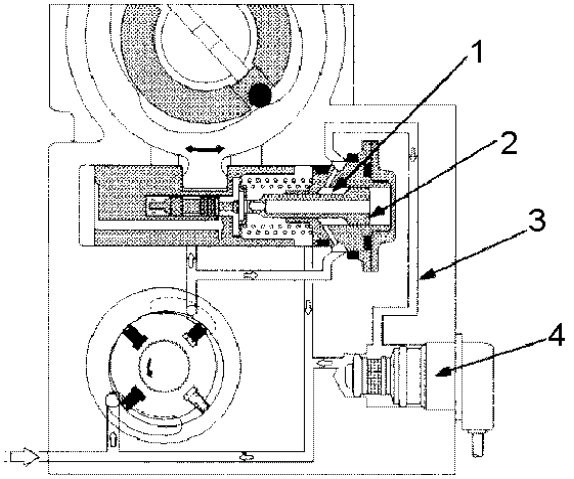
14

The fuel in the timer's high pressure chamber flows through the return channel to return to the low pressure chamber.
Because of the decrease in the high pressure chamber pressure, the timer piston is moved to the left (in the retard direction) by the timer piston return spring, and the cam ring is rotated in the retard direction.
Consequently, the cam ring's cams retard the radial plunger's beginning of compression interval to retard the beginning of injection.
Return Channel: **Open**
Inlet Channel: **Close**

The timer piston, imitating servo valve movement, is moved in a direction to cut the return channel. Consequently, the flow of fuel from the timer's high pressure camber to the low pressure chamber is stopped, and the timer piston stops in the position where the timer's high pressure chamber pressure and the set force of the timer piston return spring are in balance. (in a stabilized condition)

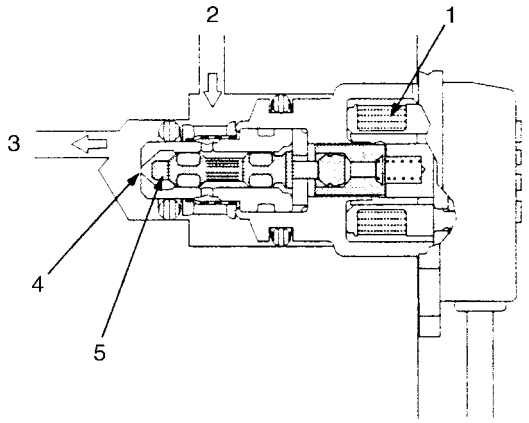
TIMING CONTROL VALVE (TCV) OPERATION

1. Annular Chamber
2. Hydraulic Stopper
3. Return Spring
4. Timing Control Valve (TCV)

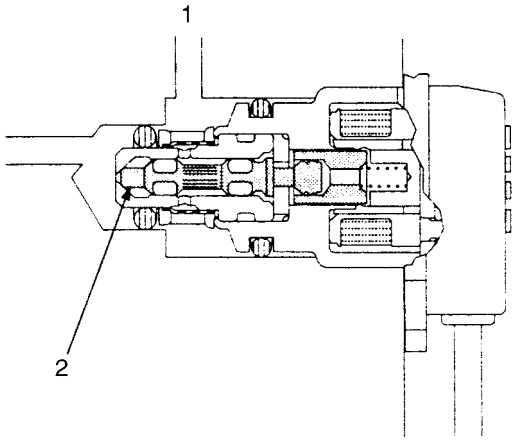


The timing control valve (TCV) acts as a variable throttle, using the rapid opening and closing (cycling) of the valve needle in the timing control valve (TCV).
At normal operation, the TCV controls the pressure acting on the annular chamber so that the hydraulic stopper cam move to any position, from the retard position to the advance position. At this time, the duty ratio is set by the pump control unit (PSG).
Duty ratio is the ratio of the time that the timing control valve (TCV) is opened to one complete timing control valve (TCV) operating cycle. A duty ratio change of 100% to 0% is an advance in injection timing. (The VP44 displays an ON duty ratio.)

1. Coil
2. From Annular Chamber
3. To Feed Pump
4. Orifice
5. Valve Needle



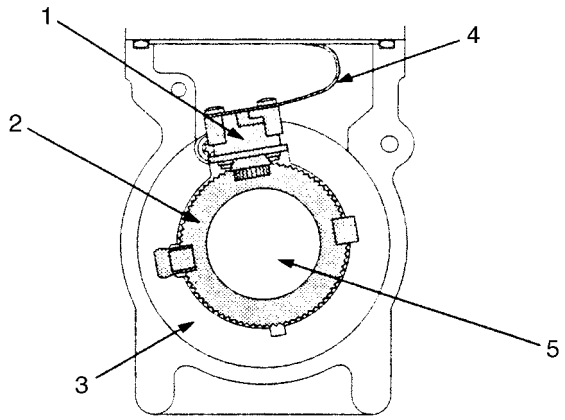
When control current flows to the timing control valve (TCV) coil, the valve needle opens and the fuel annular chamber flows through the orifice to the feed pump inlet.
Consequently, the pressure of the annular chamber decreases and the hydraulic stopper is moved to the retard side.



1. From Annular Chamber
2. Valve Needle

When control current to the timing control valve (TCV) coil is cut, the valve needle closes and the return passage is closed.
Consequently, the pressure of the annular chamber increases and the hydraulic stopper is moved to the advance side.

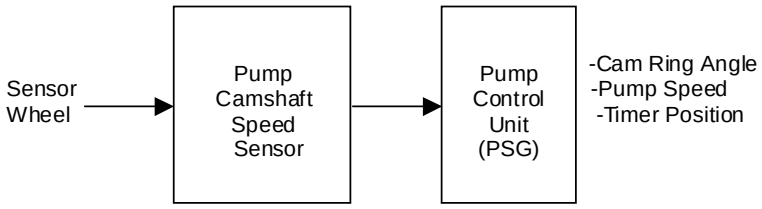
PUMP CAMSHAFT SPEED SENSOR



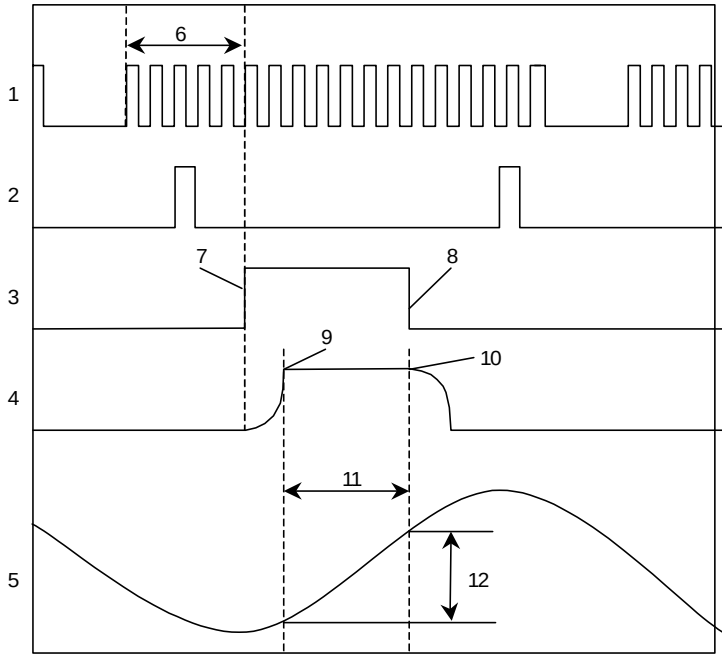
1. Pump Camshaft Speed Sensor
2. Sensor Wheel
3. Pump Camshaft Speed Sensor Retaining Ring
4. Flexible Connector Harness
5. Drive Shaft

When the drive shaft rotates, the pump camshaft speed sensor receives signal form the sensor wheel, and an electric pulse is sent through the flexible connecting harness to the pump control unit (PSG). From these signals the pump control unit (PSG) can determine the average pump speed and the momentary pump speed.
The pump camshaft speed sensor is mounted to the cam ring. Thus, the relationship between the cam ring and the pump camshaft speed sensor signal is constant.

The pump camshaft speed sensor signal is utilized for the following purposes.
To determine the momentary angular position of the cam ring.
To calculate the actual speed of the fuel injection pump.
To determine the actual timing plunger position.



1. Pump Camshaft Sensor Signal
2. Crankshaft Position Sensor Signal
3. High Pressure Solenoid Control Pulse
4. High Pressure Solenoid Needle Valve Lift
5. Cam Lift (Cam Profile)
6. Pulse Count
7. High Pressure Solenoid Valve Close
8. High Pressure Solenoid Valve Open
9. Start of Pressure Delivery
10. End of Pressure Delivery
11. Pressure Delivery Angle
11. Effective Stroke

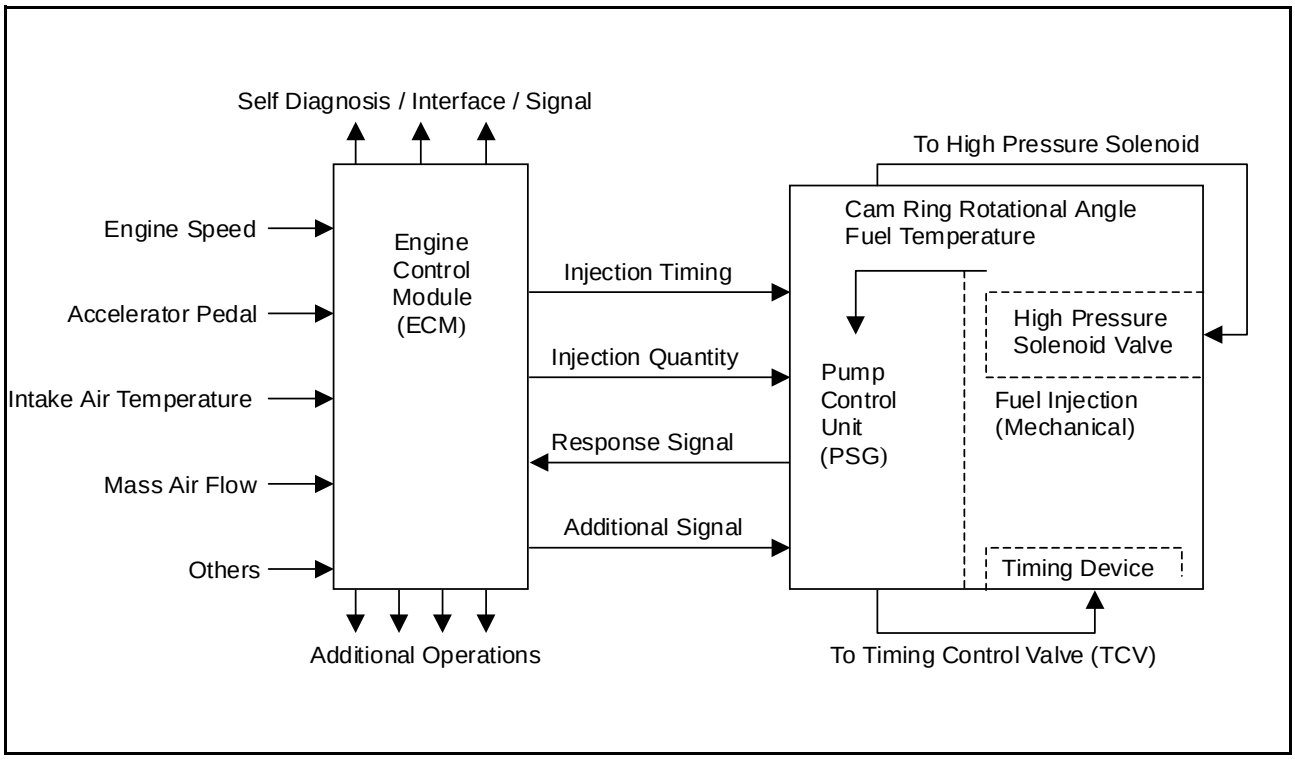


1. Momentary Cam Ring Angular Position
The momentary angular position of the cam ring is input into the pump control unit (PSG) as a high pressure solenoid valve control signal.
From momentary input of angular position for fluctuations in running conditions, the high pressure solenoid valve open and close intervals corresponding to the cam ring's cam lift can be accurately determined.

2. Actual Injection Pump Speed
When the crankshaft speed sensor is faulty, the engine control module (ECM) uses the pump speed signal as a replacement signal.

3. Actual Timing Plunger Position
The actual timing plunger position can be determined by comparing the crankshaft speed sensor signal with the pump camshaft position sensor angle.
This position is used for timer control.

PUMP CONTROL UNIT (PSG)



The radial plunger distributor type injection pump uses two control modules to execute full control of the engine management system.
Engine Control Module (ECM)
Pump Control Unit (PSG) = Pumpen Steuer Great (German)

The pump control unit (PSG) receives signals from the sensors inside the pump to determine the cam ring rotation angle, the pump speed and the fuel temperature .
These values are then compared to the desired values sent by the engine control module (ECM) such as the desired injection timing and the desired fuel injection quantity.
The engine control module (ECM) processes all engine data and data regarding the surrounding environment received from external sensors to perform any engine side adjustments.
Maps for both are encoded in both control units. The control units input circuit process sensor data.
A Microprocessor then determines the operating conditions and calculates set values for optimum running.
The interchange of data between the engine control module (ECM) and the pump control unit (PSG) is perfumed via a CAN-bus system. The abbreviation CAN stands for Controller Area Network. By having two separate control modules, the high pressure solenoid valve. This prevents the discharge of any disturbing signals.

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