ZEXEL
Bosch Group

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SERVICE MANUAL

CONSTRUCTION
& OPERATION

VP44

FOREWORD

This service manual describes the construction and operation of the VP 44 (Radial plunger distributor type fuel injection pump).
This manual is intended for use by vehicle maintenance technicians or persons with an adequate knowledge of injection pumps.

The contents of the manual, including illustrations, drawings and specifications were the latest available at the time of printing.
The right is reserved to make changes in specifications and procedures at any time without notice.

Bosch Automotive Systems Corporation
Tokyo, Japan

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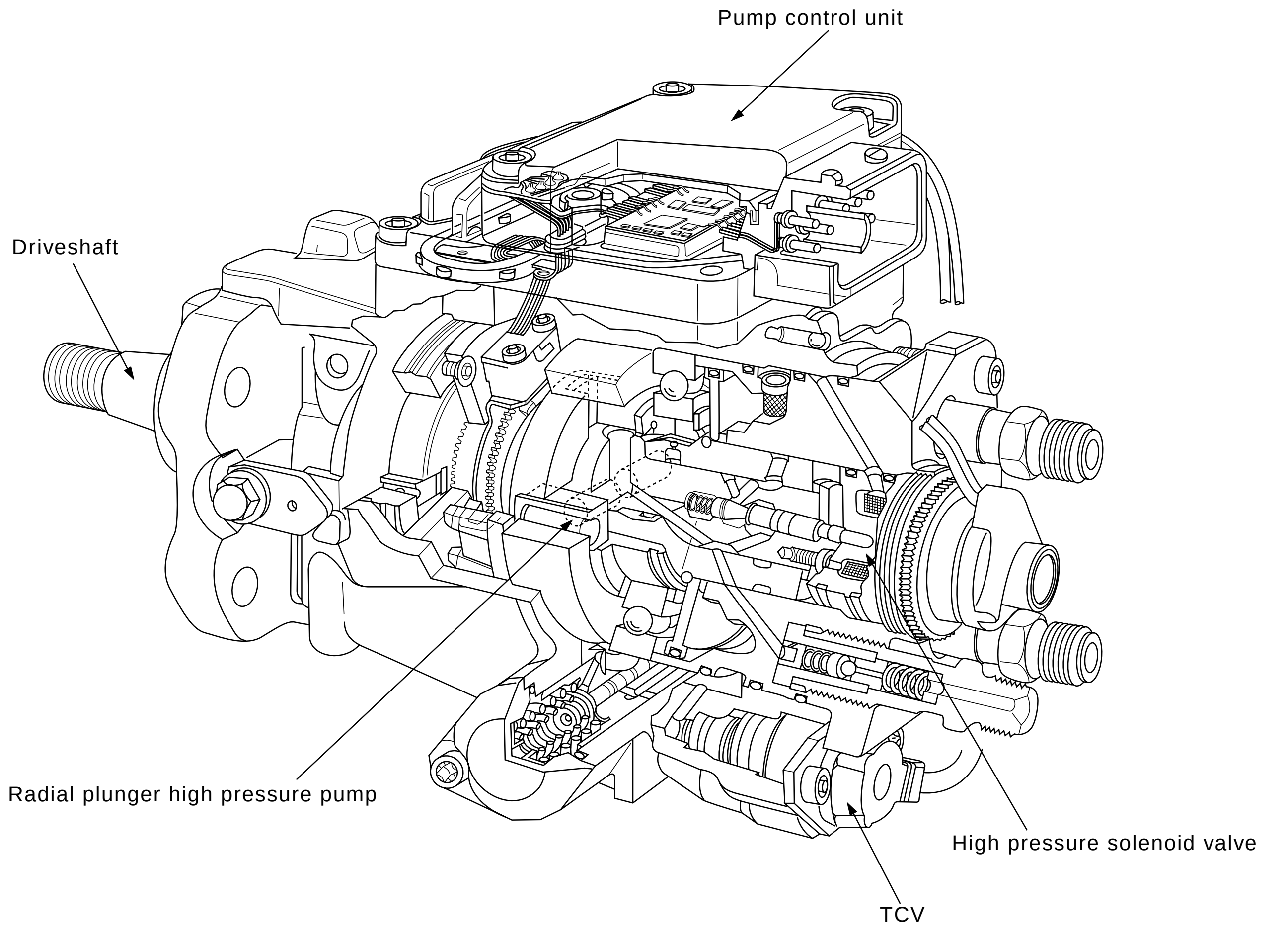
1. OUTLINE



With radial plunger distributor type fuel injection pumps, the fuel is pressurized by a radial plunger high pressure pump (with 2 or 3 cylinders, depending on the number of engine cylinders) positioned axially to the driveshaft.
Fuel injection quantity and timing are precisely controlled by two electronic control units.
A high pressure solenoid valve and a TCV (a timer) are controlled by a pump control unit installed at the top of the pump. This control unit works together with a second control unit, ie, the engine control unit (which detects such vehicle information as engine speed and accelerator pedal position), in a dual control unit system to ensure high reliability.

Instead of utilizing the previous face cam, the radial plunger distributor type fuel injection pump utilizes a cam ring to enable fuel injection at high pressures, making 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, driveability, low smoke, low noise, high output and cleaner exhaust emissions.

2. FEATURES

[1] High pressure injection

The radial plunger distributor type injection pump can generate pressure of 100 MPa {approx 1,000 kgf/cm^2} demanded by the small, fuel efficient, high pressure, high speed direct injection diesel engines.

[2] High pressure atomization of fuel injected from the nozzle

Through high pressure injection of fuel, the fuel injection from the nozzle 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) so that combustion is improved. This contributes to cleaner emissions.

[3] Optimum fuel injection system

High speed control of fuel injection quantity and fuel injection timing suitable for the engine is performed by the control unit, enabling lower fuel cost and high output.

[4] Improved endurance

The components used in the pump are very resistant to high pressure, ensuring improved endurance.

[5] Improved engine matching

As fuel injection to the engine can be controlled for each cylinder, matching to the engine is improved.

[6] Improved reliability

As a dual control unit system with both an engine control unit and a pump control unit is used, the control system is extremely reliable.

[7] Improved power performance

As the optimum fuel injection quantity corresponding to accelerator position is controlled by the control unit, increased torque in low accelerator pedal positions is possible, enabling improved power performance.

[8] Decreased smoke at acceleration

When fuel injection is increased to increase engine power at acceleration, smoke is usually generated by the excess fuel. The VP44 fuel injection pump, however, 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 compensation is made by the control unit based on signals from each sensor. This results in less ‘clutter’ around the injection pump.

[10] Self diagnosis function

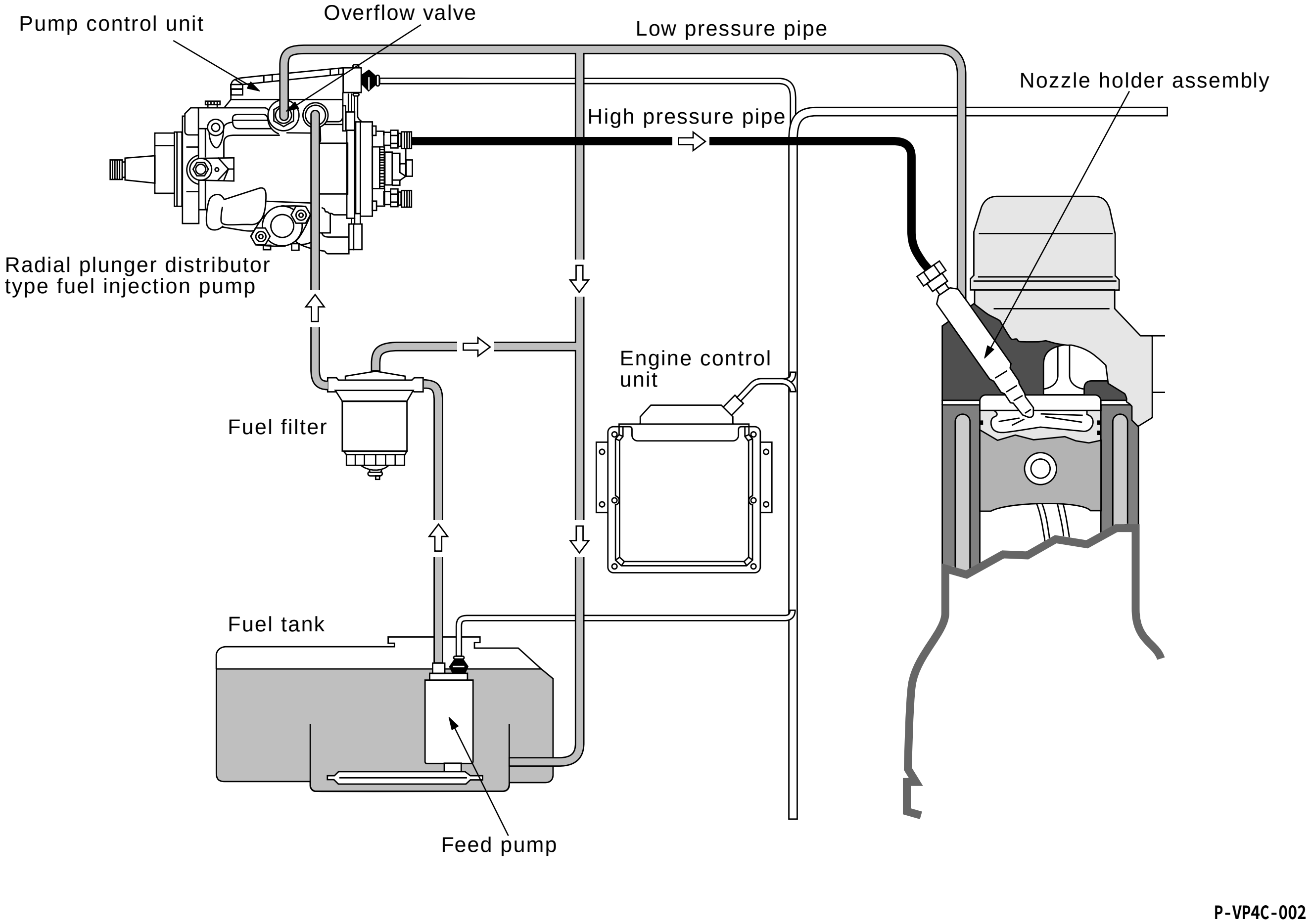
The system includes a self diagnosis function which displays error codes to facilitate the diagnosis of malfunctions.

3. SPECIFICATIONS

Item	Specifications
Injection pump type	VP44
Applicable vehicles	Passenger vehicles, recreational vehicles, small and medium sized trucks (less than 1ℓ / cylinder)
Applicable number of engine cylinders	4 cylinders, 6 cylinders
Direction of rotation	Clockwise / counter clockwise
Drive method	Toothed belt, gear, chain
Injection performance Maximum pump pressure Plunger diameter x number Maximum lift Maximum plunger speed Maximum allowable drive torque	 100 MPa {approx 1000 kgf/cm^2} 4 cylinder: φ6.5 mm x 2, φ7 mm x 2, φ7.5 mm x 2 6 cylinder: φ7 mm x 3, φ7.5 mm x 3 3.5 mm 1.9 m/second: 1000 r/min 200 N.m {20.4 kgf.m}: 3 holed flange 260 N.m {26.5 kgf.m: 4 holed flange (Maximum drive torque necessary under actual usage conditions: 150 N.m {15.3 kgf.m} limit)
System Minimum drive voltage Maximum high pressure solenoid valve current Control unit type Battery specification	 6V ≦20 A Engine control unit, pump control unit (dual control unit system) 12V specification, 24V specification
Standard performance Standard control method Timing feed back Compensation for variation between pump fuel injection quantities Timer advance angle range	 Fuel injection quantity control: high pressure solenoid valve, time control Injection timing control: TCV duty solenoid system, hydraulic timer Cam position feed back Pump EPROM, multi point compensation Maximum advance angle: 15°
Pump size	Identical to COVEC-F
Weight	Approx 8.0 kg

4. FUEL SYSTEM

[1] Fuel system schematic



(1) Fuel piping system

Centering around 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 the 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 feed pumps in the fuel tank and the injection pump, after first passing through the fuel filter.

The fuel filter is installed to filter the fuel, and also has a sedimenter in the bottom to separate any water from the fuel.

(3) Regulating fuel feed pressure and delivery pressure

The fuel taken 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.

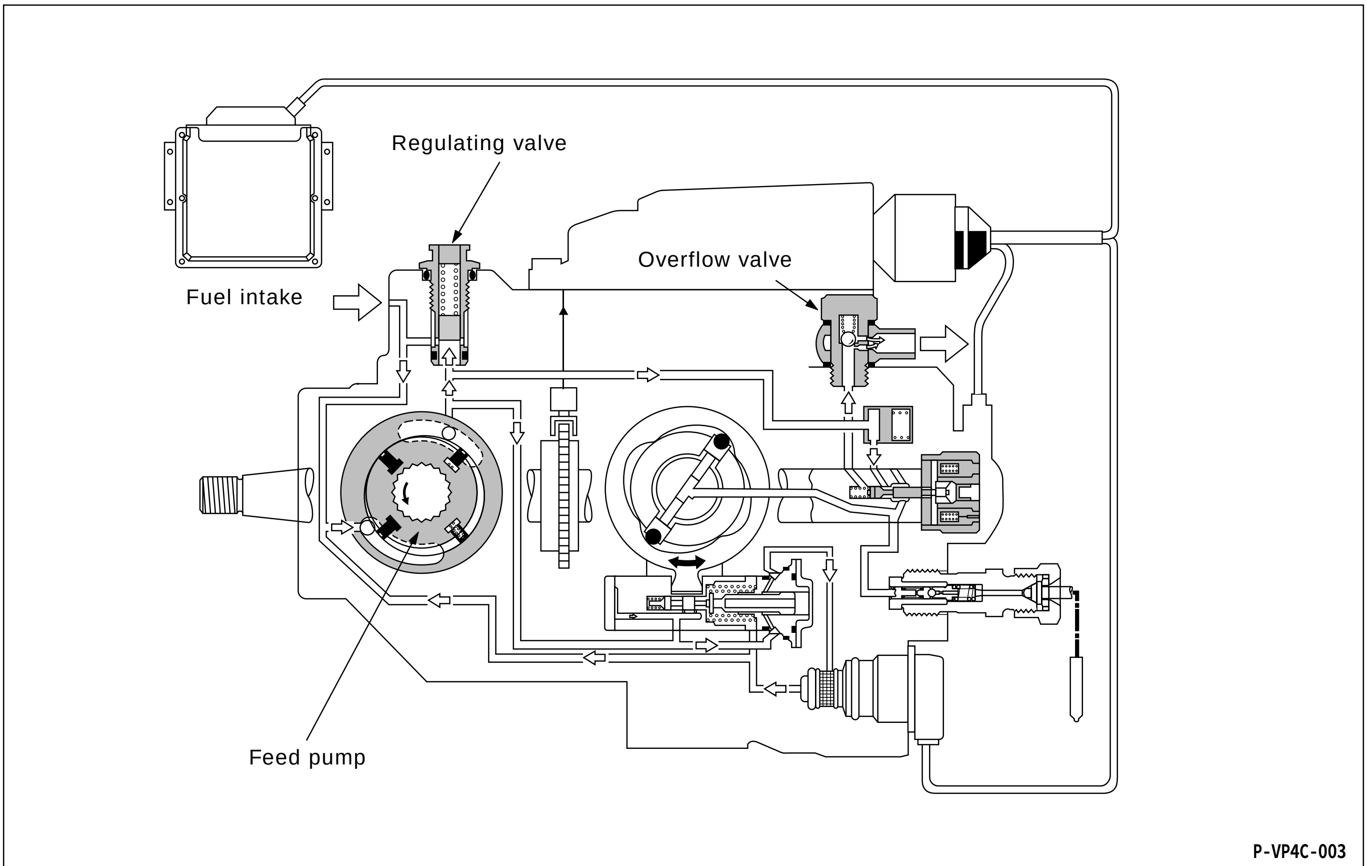
(4) Fuel pressurization

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

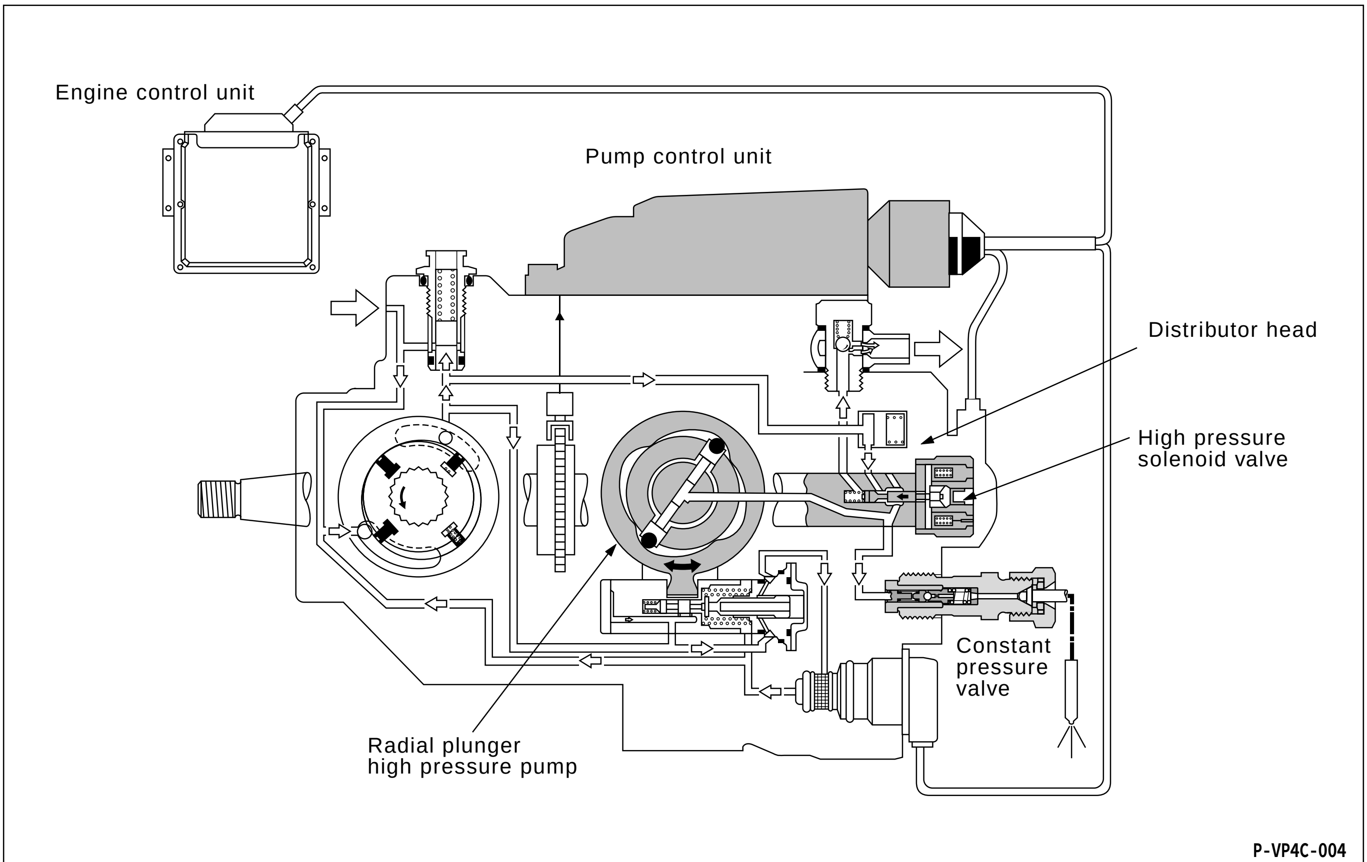
(5) Determining the optimum fuel injection quantity and fuel injection timing

The optimum quantity of high pressure fuel is pressure fed to the nozzle holder assembly at the optimum timing by the high pressure solenoid valve and the TCV (timer) controlled by the pump control unit.

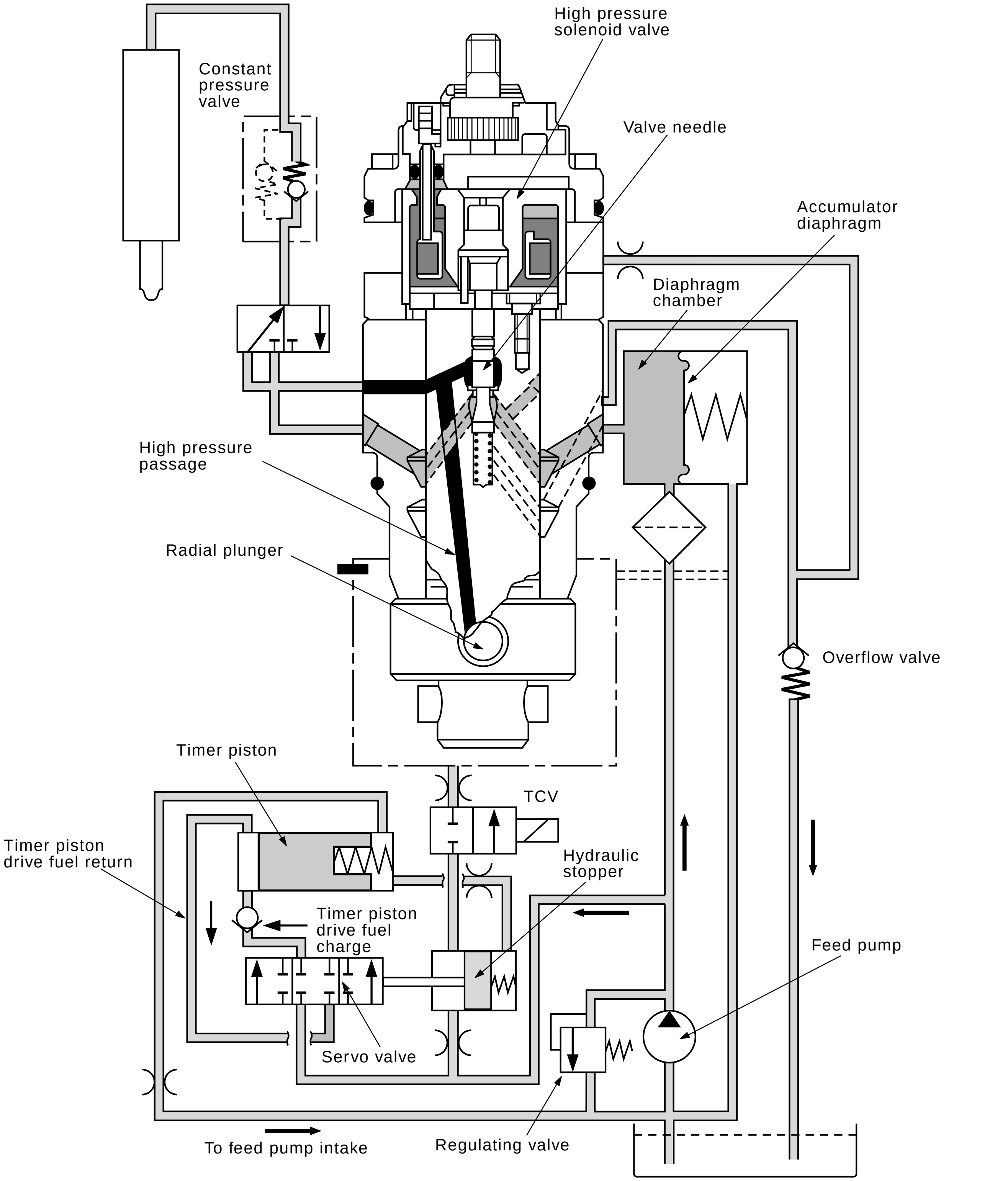
[2] Injection pump fuel intake system



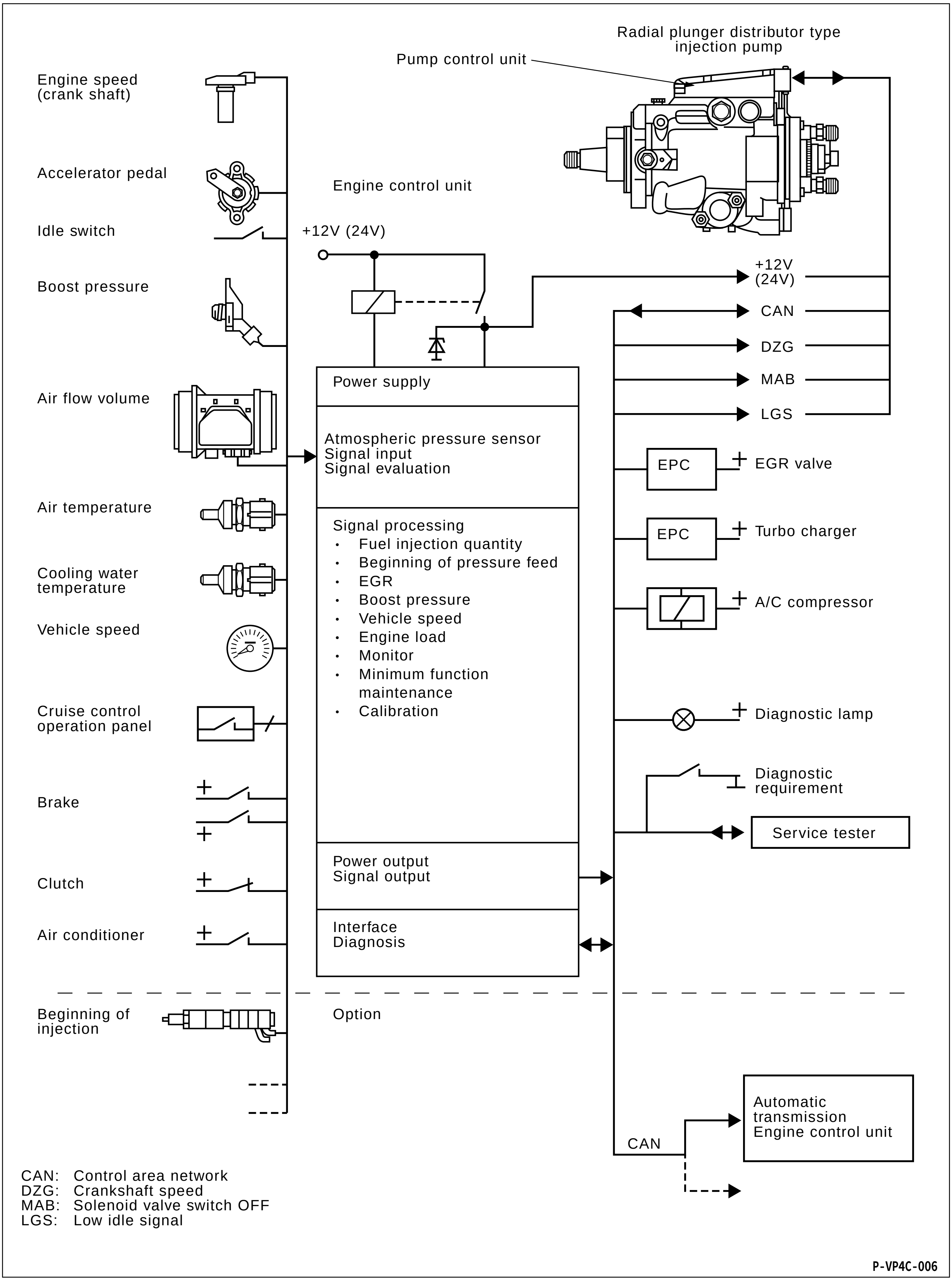
[3] Injection pump fuel pressure feed system



[4] Fuel pressurization control

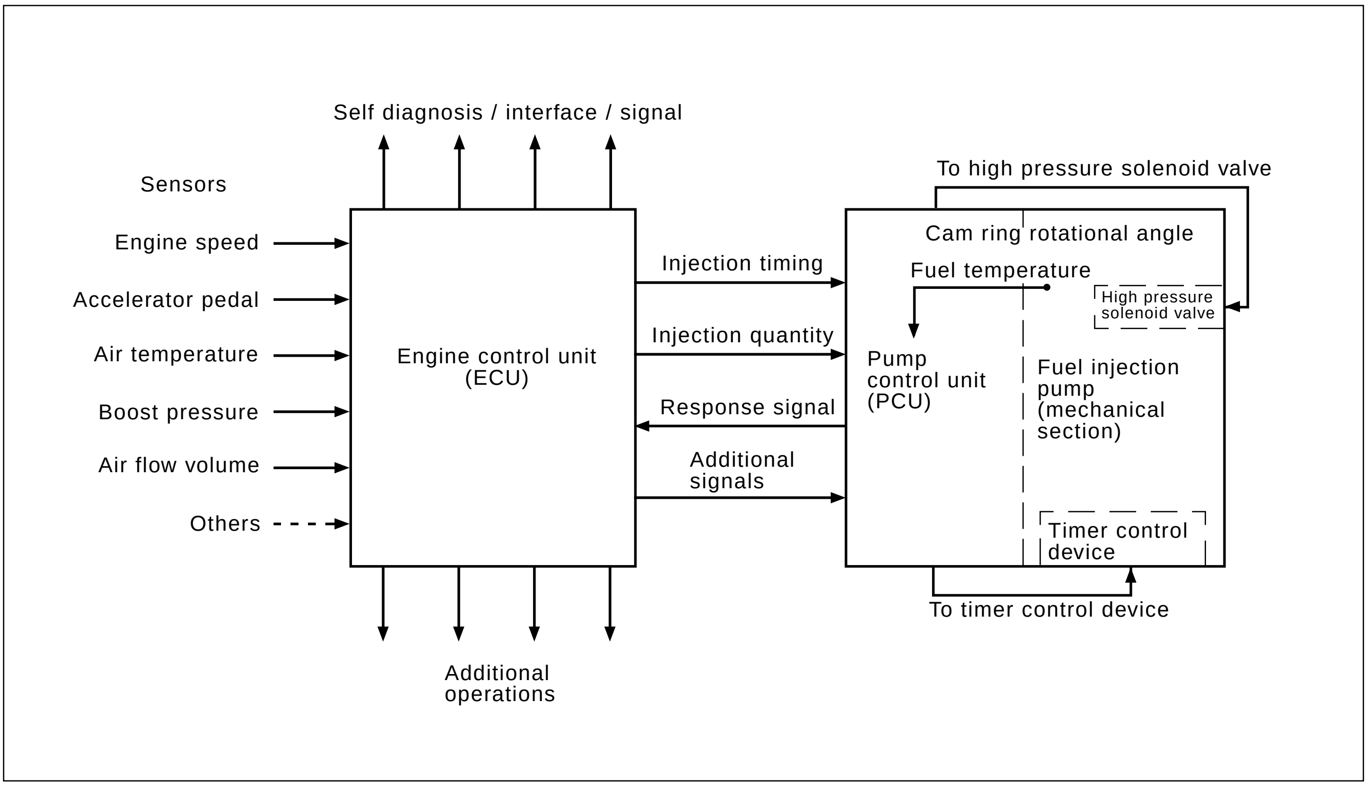


5. SYSTEM CONTROL DIAGRAM

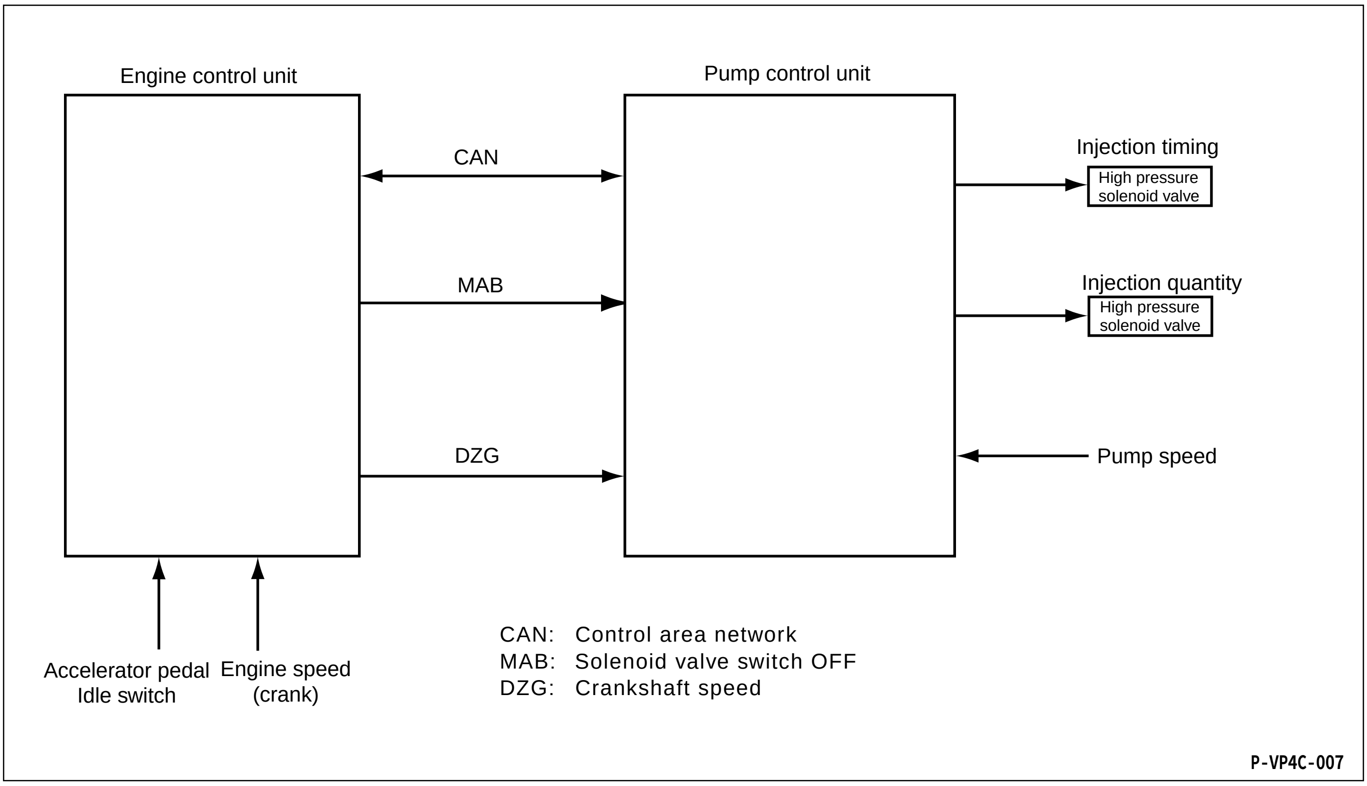


6. CONTROL UNIT SYSTEM CONTROL DIAGRAMS

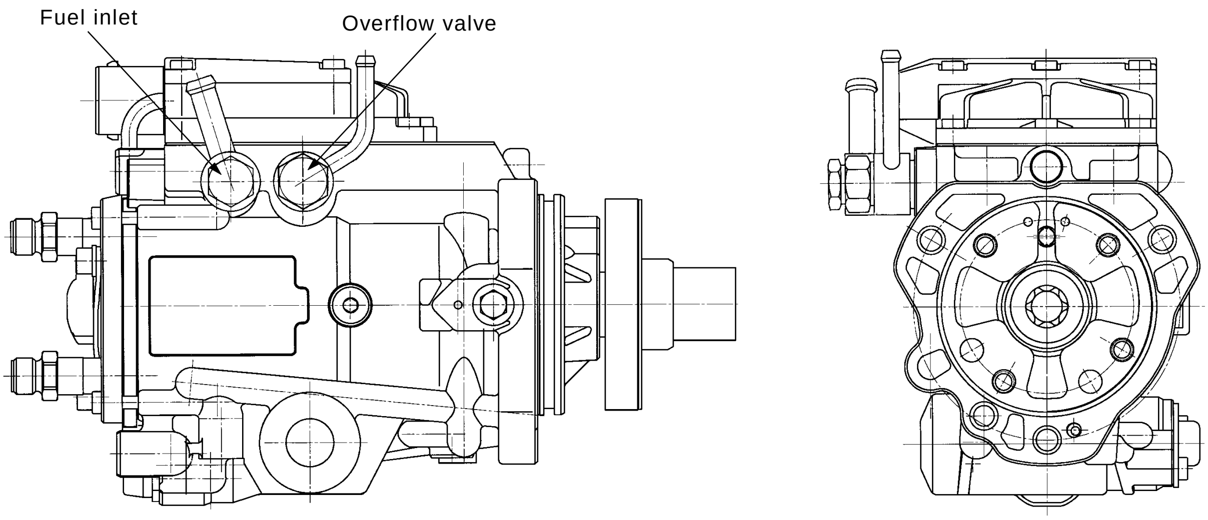
[1] Block diagram



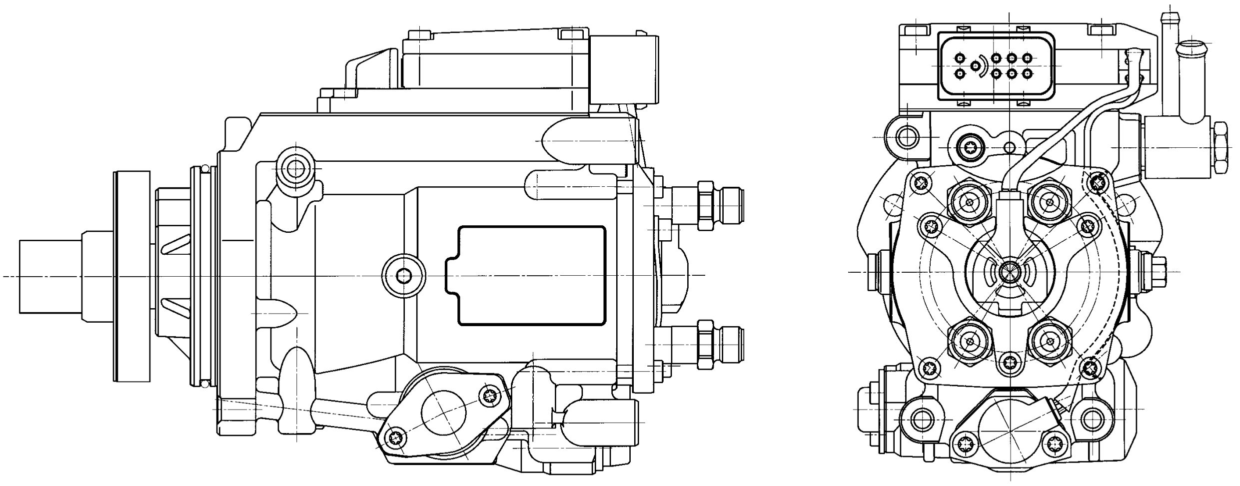
[2] Circuit diagram



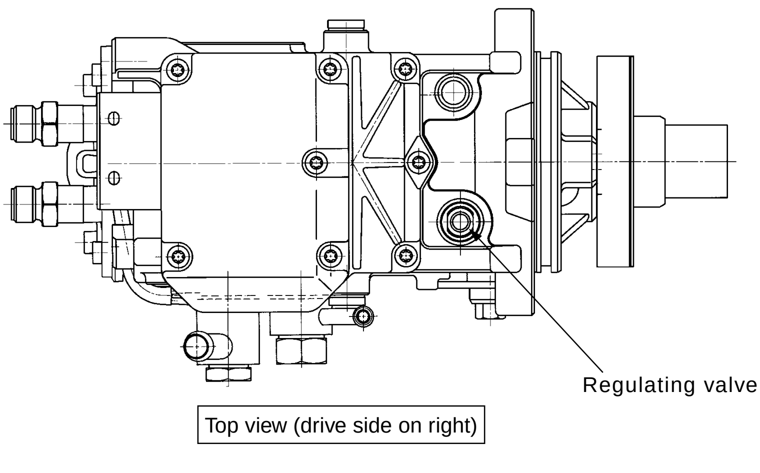
1. EXTERNAL VIEW



Side view (drive side on right)



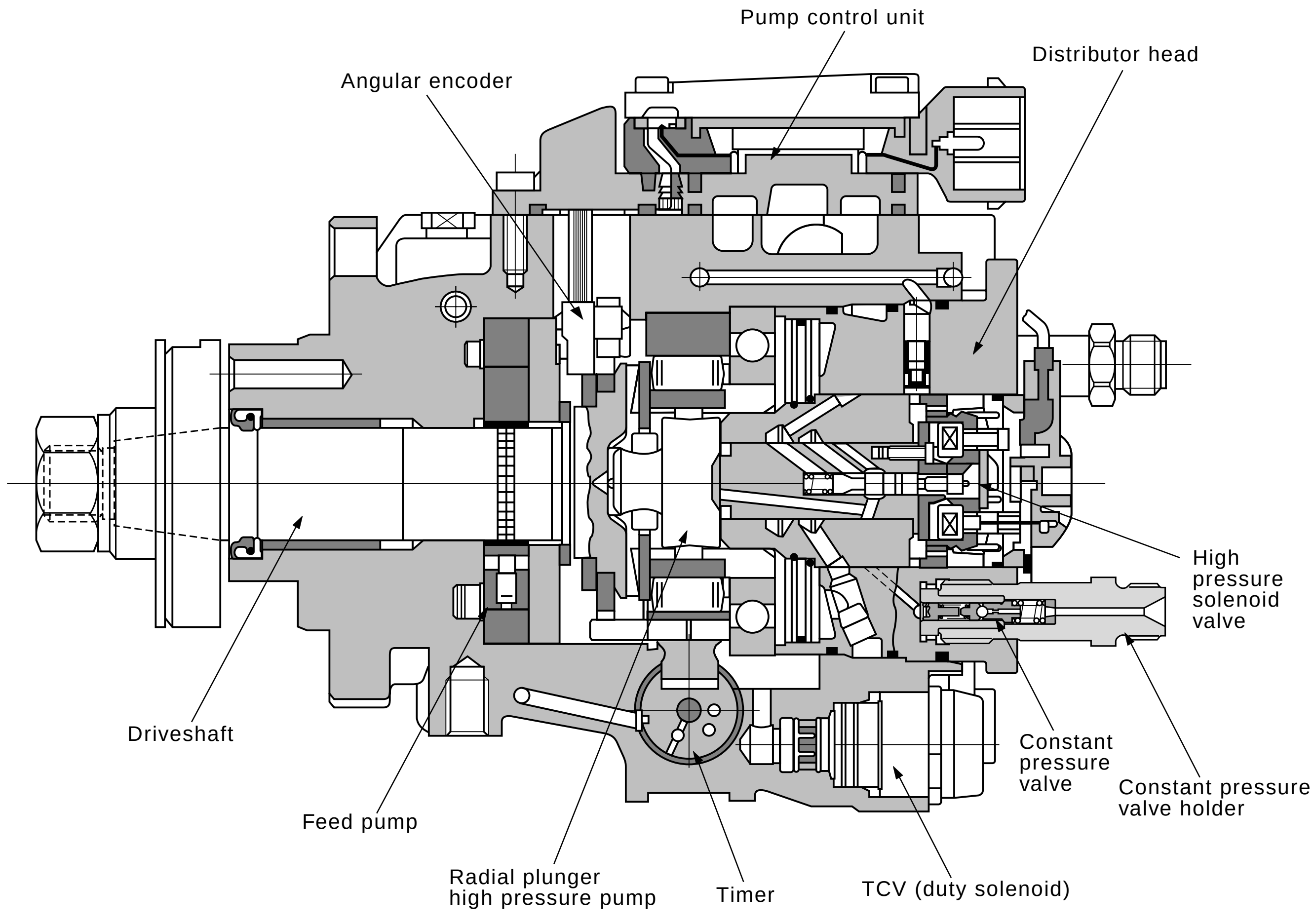
Side view (drive side on left)



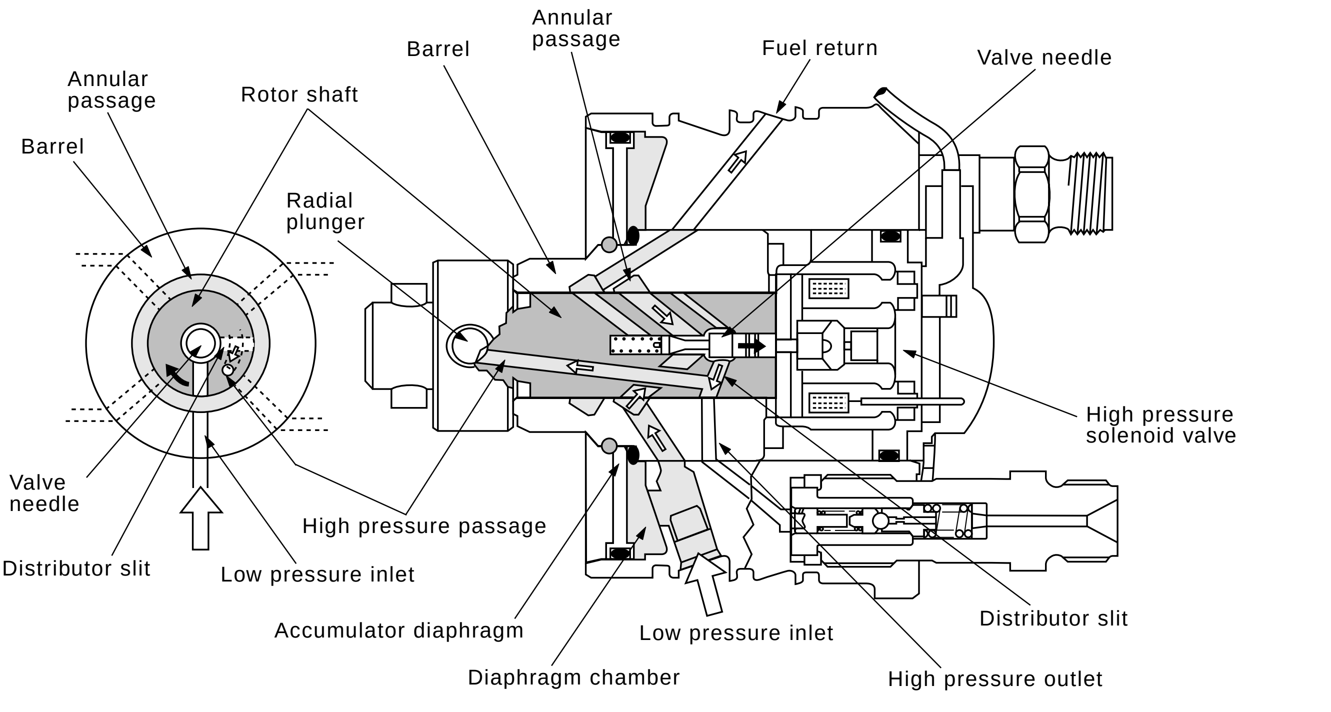
Top view (drive side on right)

P-VP4C-008

2. CROSS-SECTIONAL VIEW



P-VP4C-009



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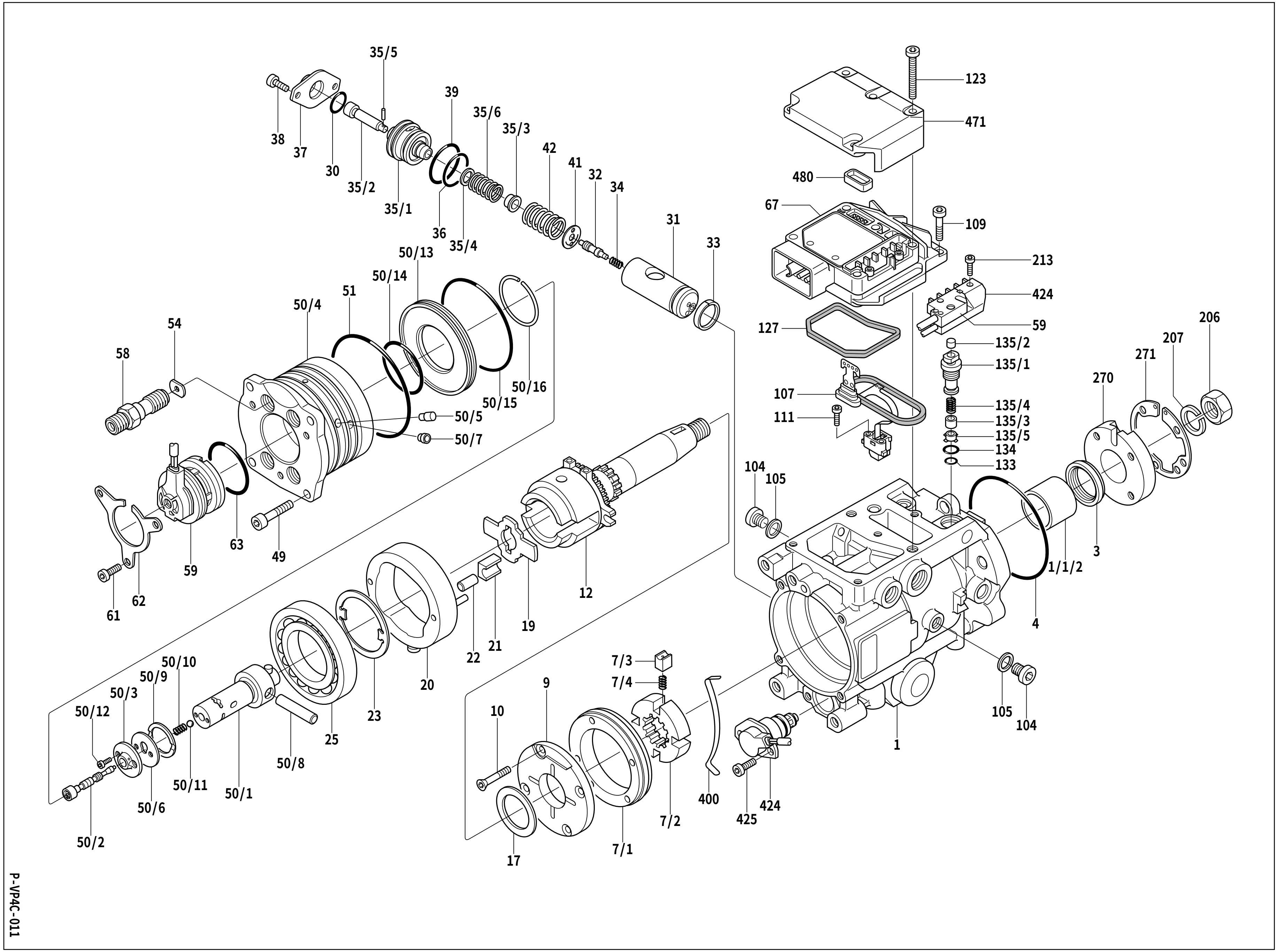
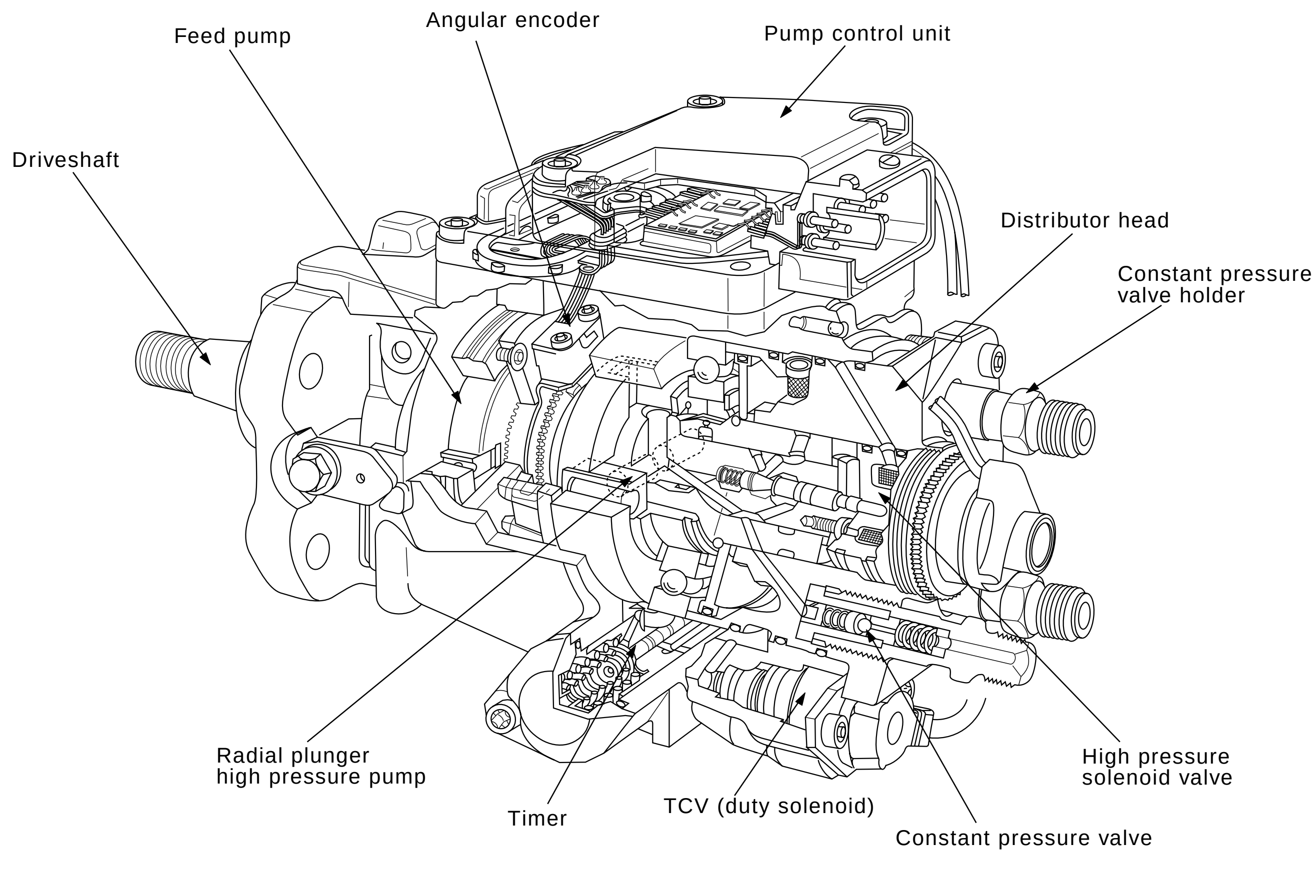
3. EXPLODED VIEW



P-VP4C-011

4. CONSTRUCTION

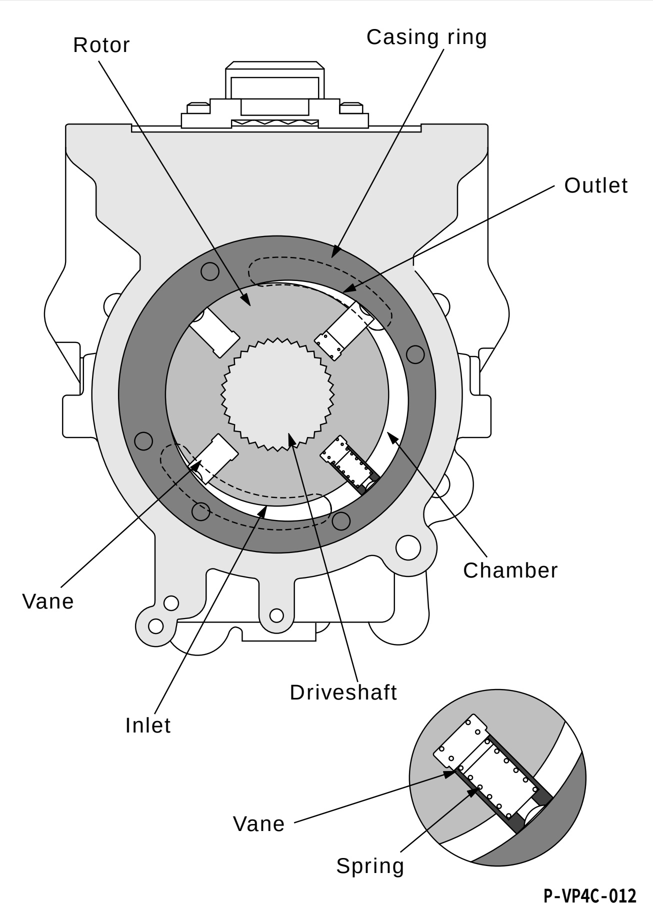
[1] Fuel injection pump body



The following functional components are located either inside the radial plunger distributor type injection pump housing or compactly installed on the pump.

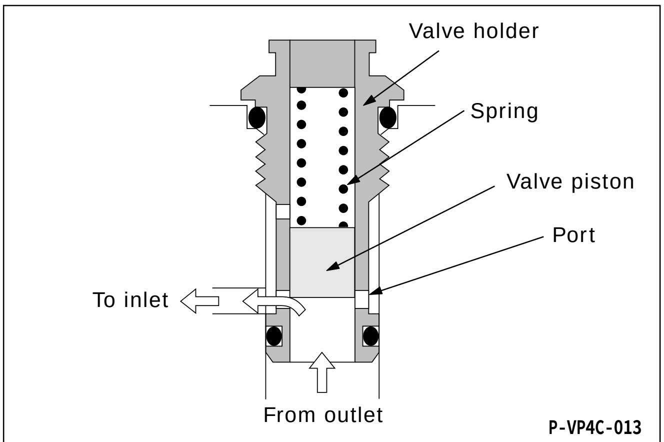
- Feed pump (a vane type pump) and regulating valve
- Radial plunger high pressure pump and constant pressure valve
- Distributor head
- High pressure solenoid valve
- Timer and TCV (duty solenoid)
- Angular encoder
- Pump control unit

Through the combination of each component's functions, the strictly defined target values are maintained and the performance characteristics demanded by the engine are satisfied.
The radial plunger distributor type injection pump is fixed directly to the engine by a flange and driven by a chain, gear or toothed belt. To prevent mistaken installation of the injection pipes, symbols (A, B...F) are marked on the distributor head on the side of the constant pressure valve so that each constant pressure valve holder can be matched with its corresponding engine cylinder.



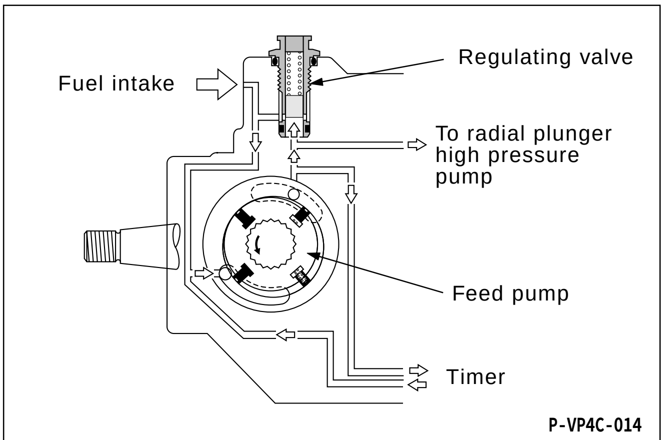
[2] Feed pump (low pressure section)

The feed pump consists of a rotor, vanes and a casing ring. The rotor is driven by the driveshaft. 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 driveshaft, 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 maintains the fuel delivery pressure from the outlet at a pressure not exceeding a specified pressure.

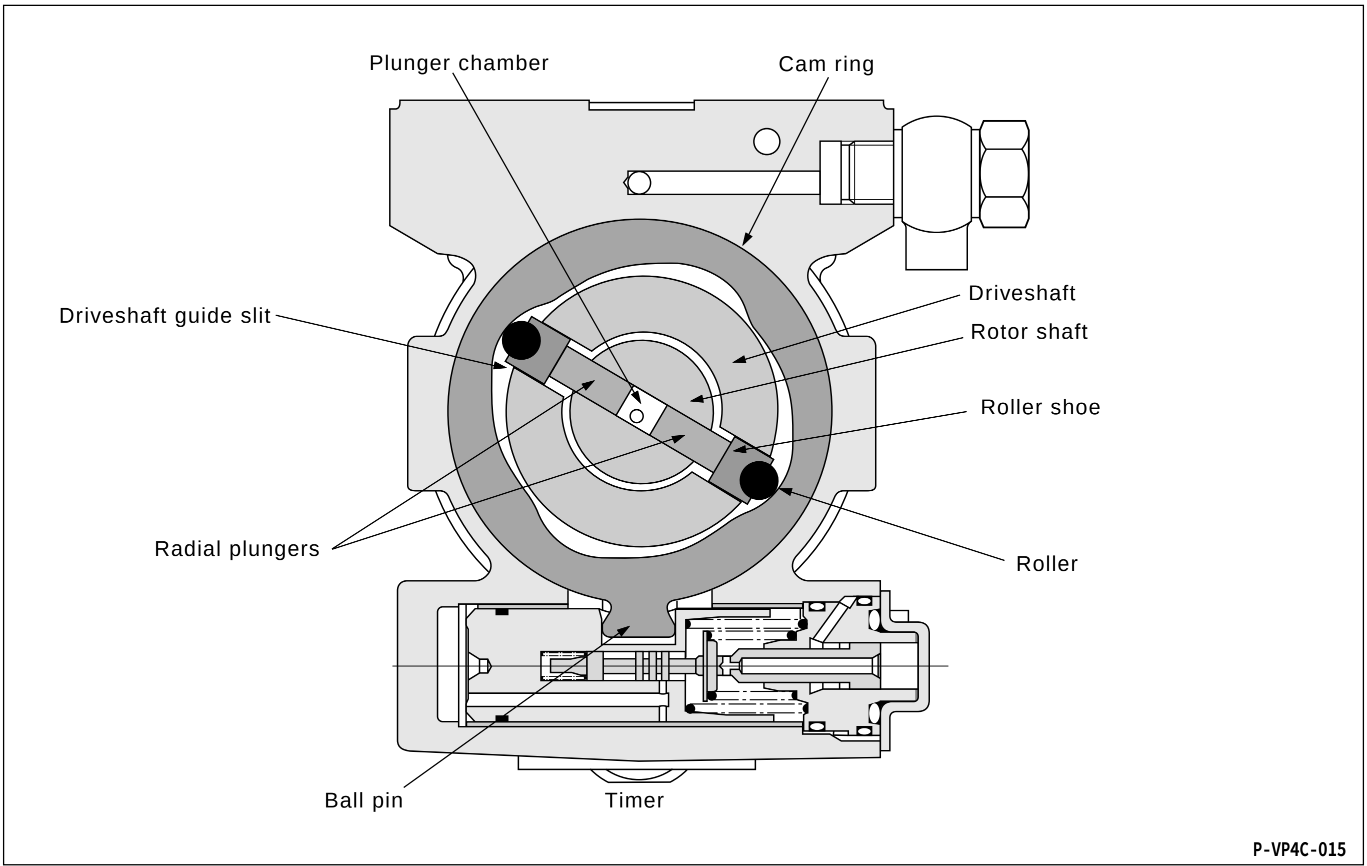


[3] Regulating valve

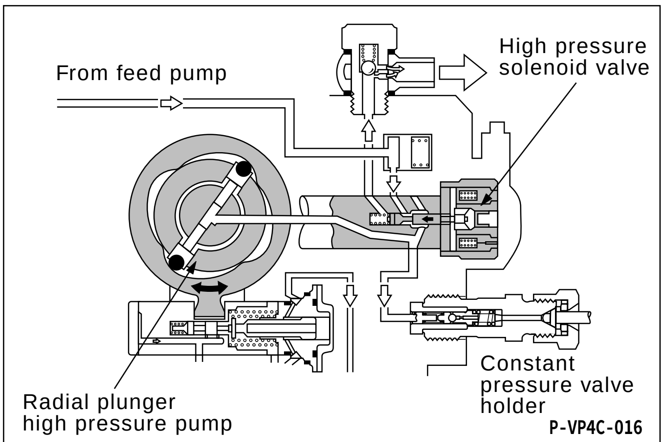
The regulating valve consists of a valve holder, a spring and a valve piston. Ports are arranged radially in the valve holder.
The valve piston is pushed to block the ports by the spring force.
The valve piston opening pressure can be adjusted by adjusting the spring's set force.



[4] Radial plunger high pressure pump (high pressure section)

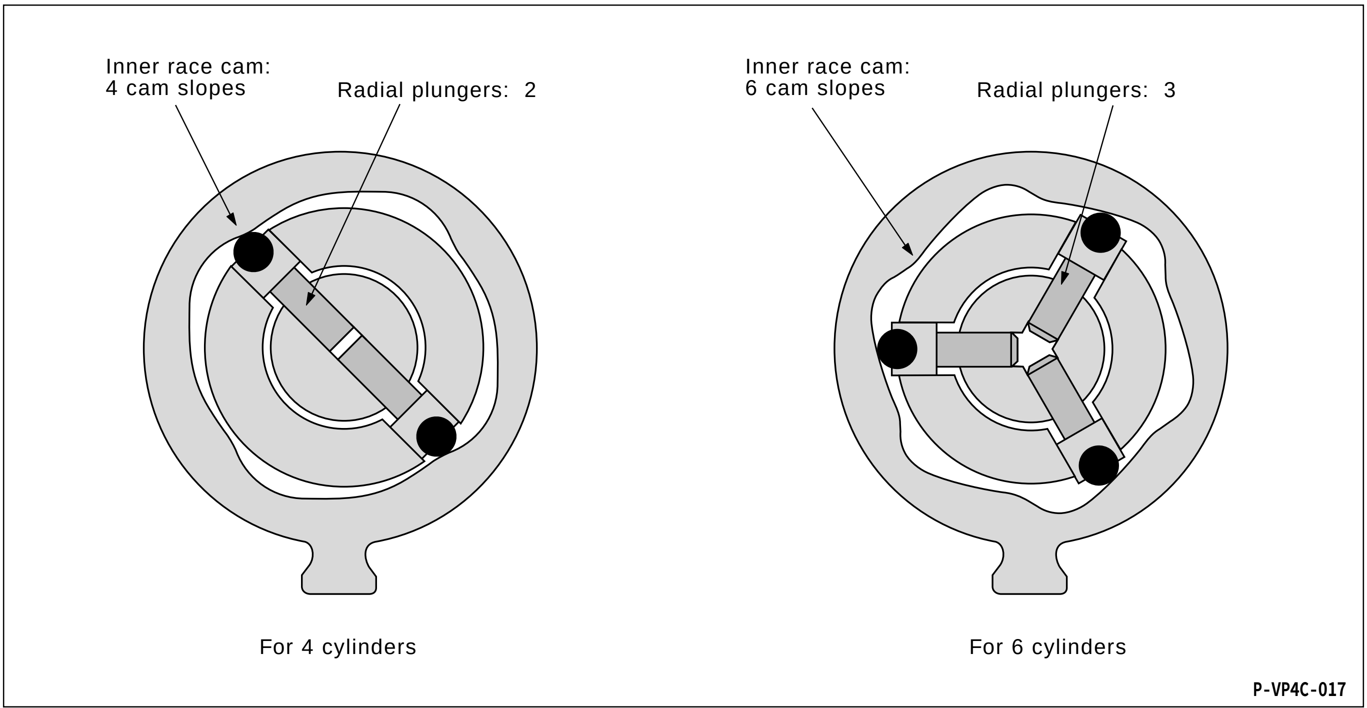


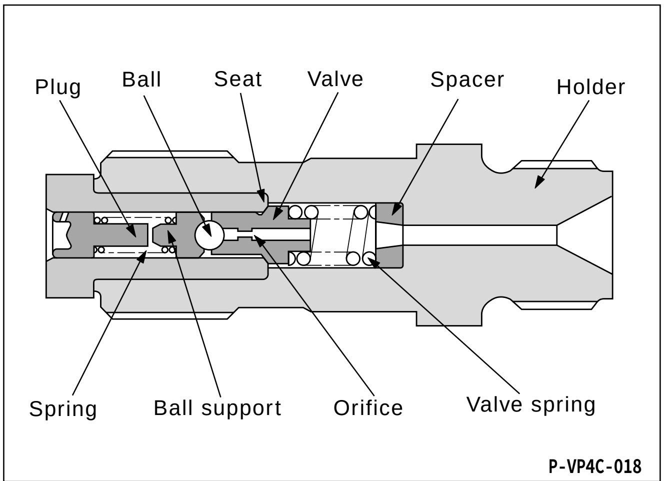
- The radial plunger high pressure pump consists of a cam ring, a rotor shaft, roller shoes, rollers and radial plungers.
  The cam ring has cams on the inner race (4 cylinder engines: 4 cams; 6 cylinder engines: 6 cams) and the outer race is connected to the timer by a ball pin.
  The rotor shaft is driven by a fuse plate connected to the driveshaft. The radial plungers are assembled inside the rotor shaft.
  The radial plungers are pushed against the cam faces by feed pump delivery pressure via the roller shoes assembled in the driveshaft's guide slits and the rollers.
  With driveshaft rotation, the radial plungers are pushed in towards the center of the rotor shaft by the cams ring's inner race cams to compress the fuel.



- The suction and compression of fuel into the radial plunger high pressure pump are controlled by the high pressure solenoid valve.

- Types of radial plunger high pressure pump
  There are either two or three radial plungers, depending on the number of engine cylinders.



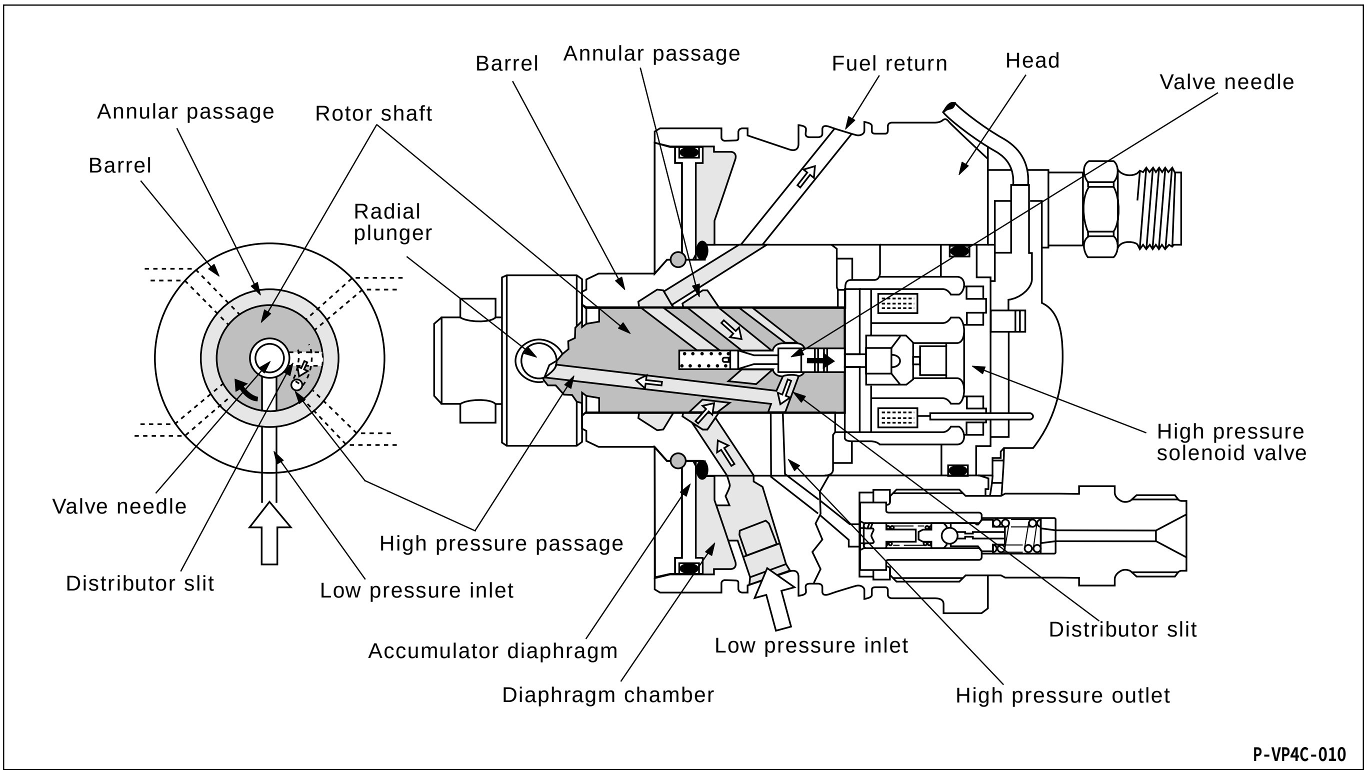


[5] Constant pressure valve (CPV)

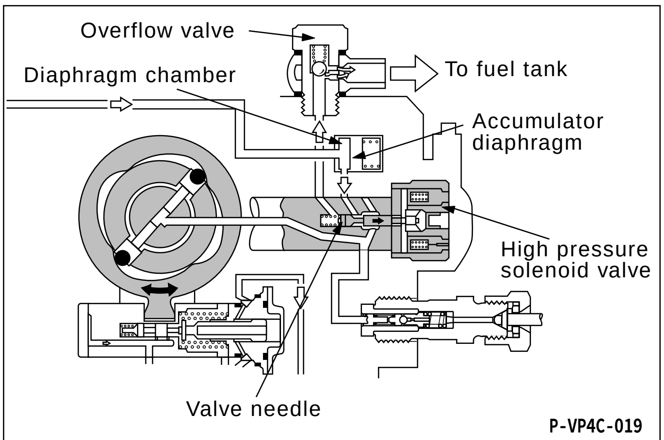
The constant pressure valve (CPV) consists of a holder, a spacer, a valve spring, a valve, a seat, a ball, a ball support, a spring and a plug. The valve is equipped with an orifice to suppress the reflected pressure wave (the cause of secondary injection) that results at nozzle closing at the end of injection.

The valve is opened by high pressure fuel and this high pressure fuel is delivered to the nozzle holder assembly.

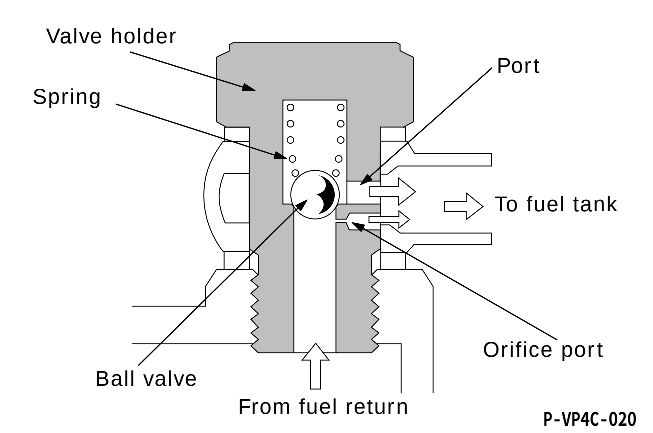
[6] Distributor head

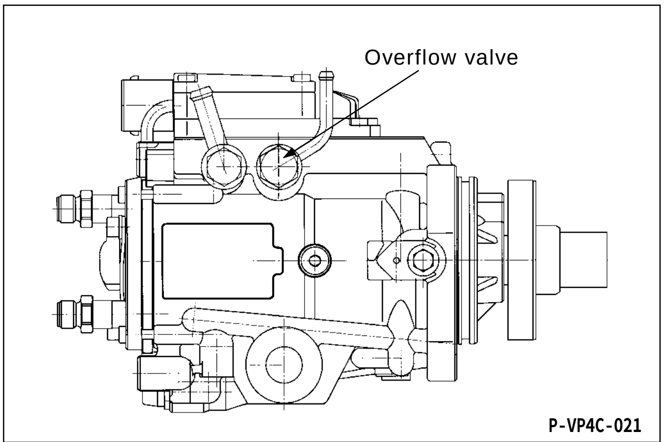


- The distributor head consists of a head, a barrel pressfitted to the head, a rotor shaft which slides inside the barrel, a high pressure solenoid valve needle and an accumulator diaphragm.
  The fuel oil supplied by the feed pump flows through the low pressure inlet, the accumulator diaphragm chamber and an annular passage.
  During the fuel suction process, the high pressure solenoid valve's valve needle seat is open (as the current is OFF) and fuel fills the high pressure passage.
  The radial plunger is pushed outwards (towards the cam ring) by the feed pump's fuel delivery pressure, 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's valve seat is closed (as the current is ON). The high pressure fuel compressed by the radial plunger, through rotor shaft rotation, flows through the distributor slits connected to the injection cylinder's high pressure outlets and to the nozzle holder assembly via the constant pressure valve holder.



- At the end of injection, the high pressure solenoid valve current is turned OFF and the valve needle seat is opened, although compression 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.





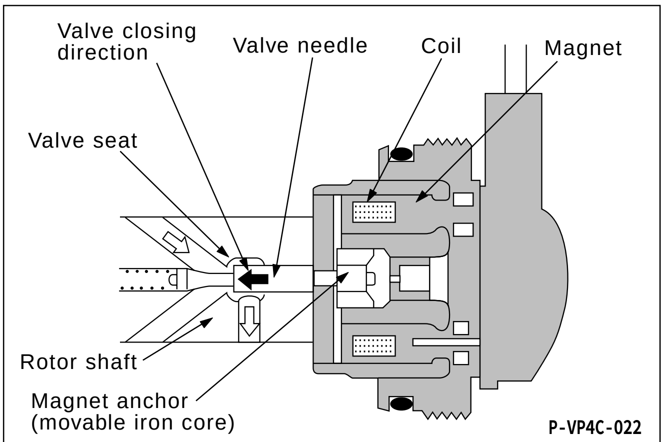
[7] Overflow valve

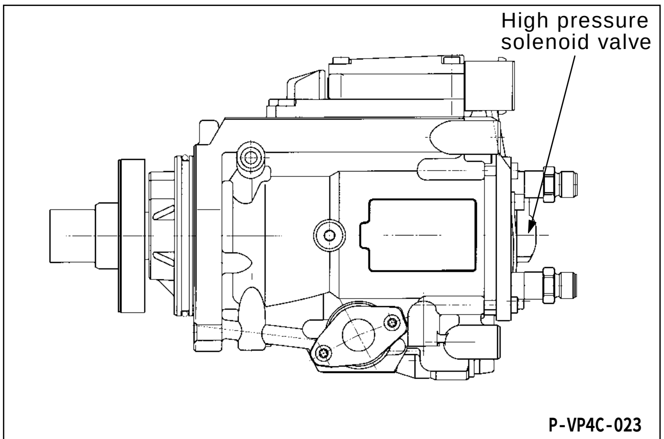
The overflow valve consists of a valve holder, a spring and a ball valve, and is installed on the side of the injection pump.

The valve holder is equipped with a port and an orifice port. The orifice port assists in automatic air bleeding.

When the excess fuel returned from the distributor head's fuel return exceeds a specified pressure, the fuel pressure pushes the ball valve up so that the fuel can return to the fuel tank.

The overflow valve maintains the returned fuel at a specified pressure, and also works to cool the injection pump body.





[8] High pressure solenoid valve

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

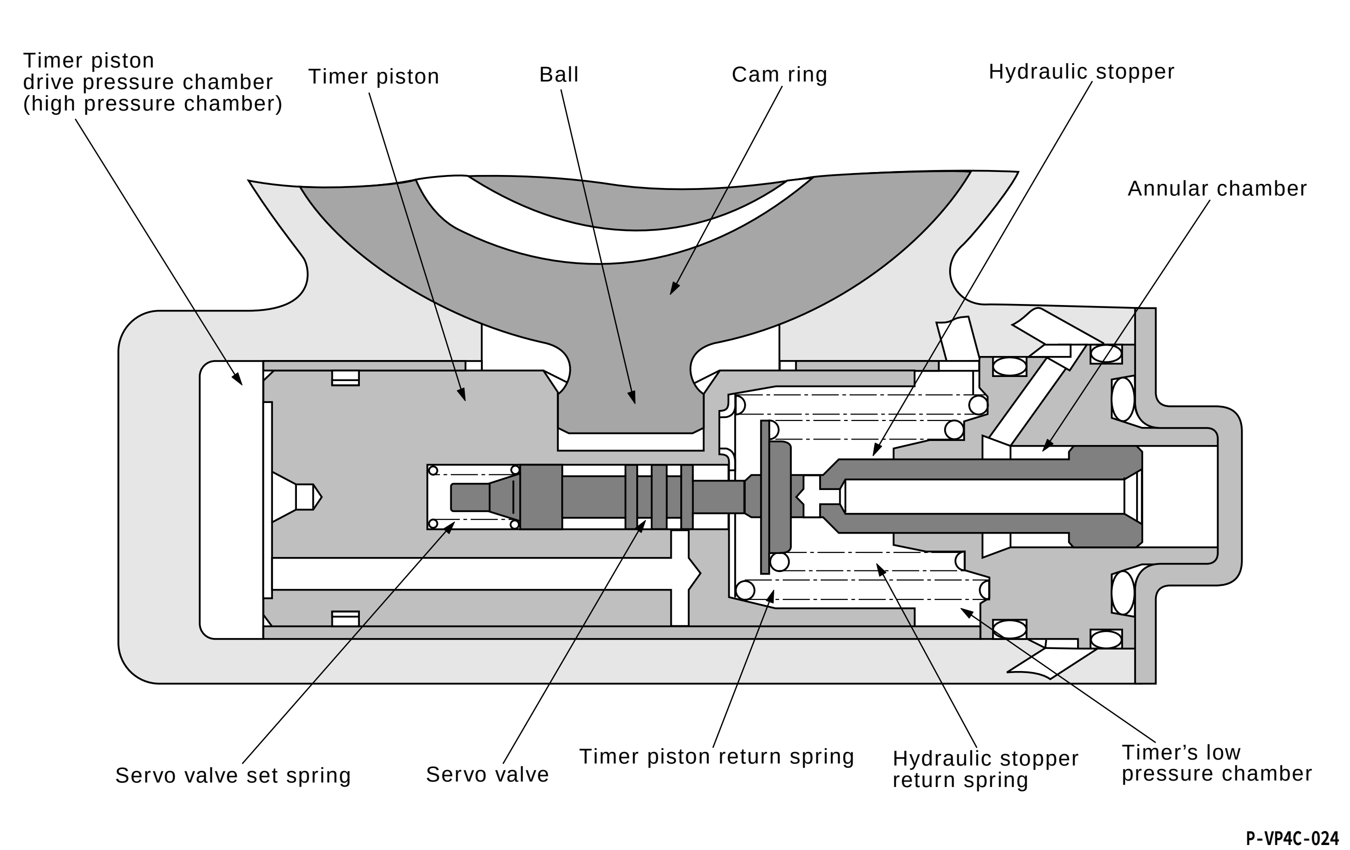
When current controlled by the pump control unit flows to the coil, the magnet anchor and the valve needle are pushed towards the valve seat.

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.

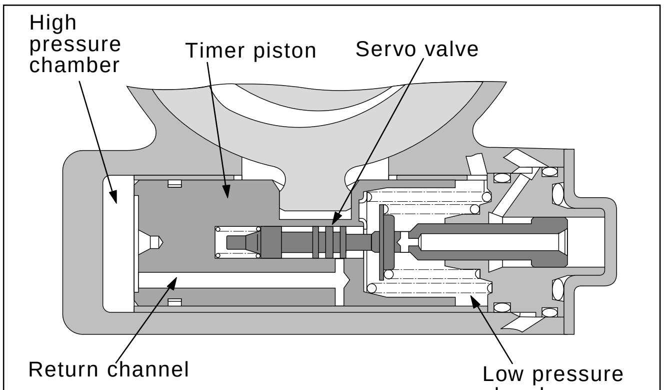
When the injection quantity reaches that demanded by the engine, the current to the coil is cut, the valve seat opens and injection of fuel is completed.

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

[9] Timer

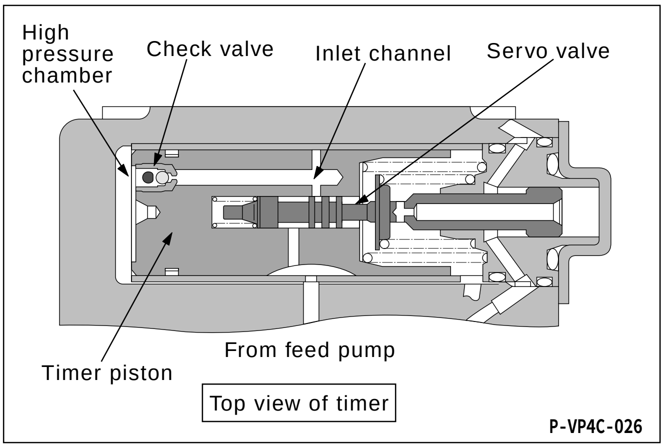


- The timer consists of a timer piston, a servo valve, a servo valve set spring, a hydraulic stopper, a hydraulic stopper return spring and a timer piston return spring.
  The timer is installed on the bottom of the pump housing at right angles to the injection pump's axial orientation.
  The timer piston is connected to the ball of the cam ring so that axial movement of the timer piston is converted to cam ring rotation.
  The timer piston 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 TCV.

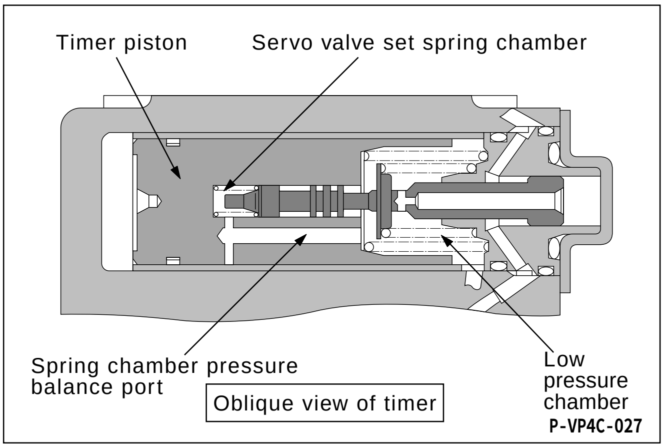


Side view of the timer

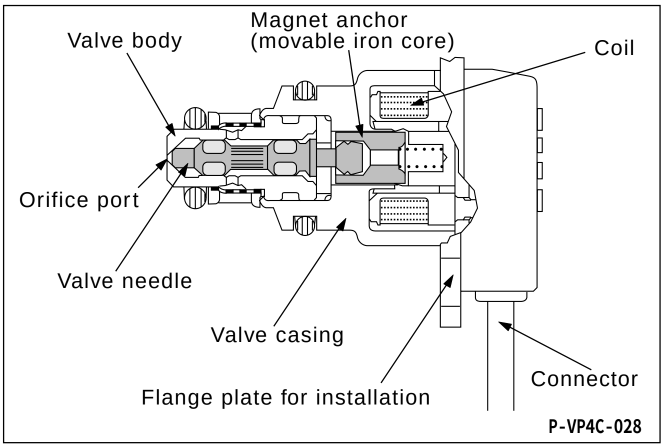
- The left hand figure shows a side view of the timer.
  The timer piston has a return channel connecting the high pressure chamber to the low pressure chamber through the servo valve. (This is the return passage for fuel at timer piston retard.)



- The left hand figure shows a top view of the timer.
  The timer piston has an inlet channel connecting the high pressure chamber and the feed pump's outlet side passage through the servo valve. (This is the fuel passage at timer piston advance.)
  The inlet channel is equipped with a check valve (with a ball valve on the orifice side, and a pin pressfitted on the opposite side) to prevent reverse flow from the high pressure chamber to the feed pump.

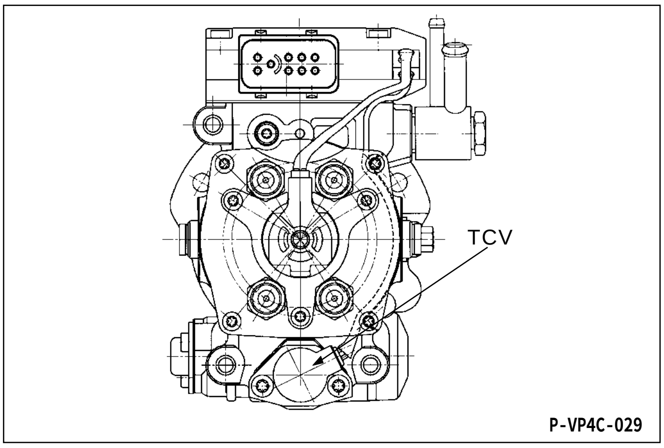


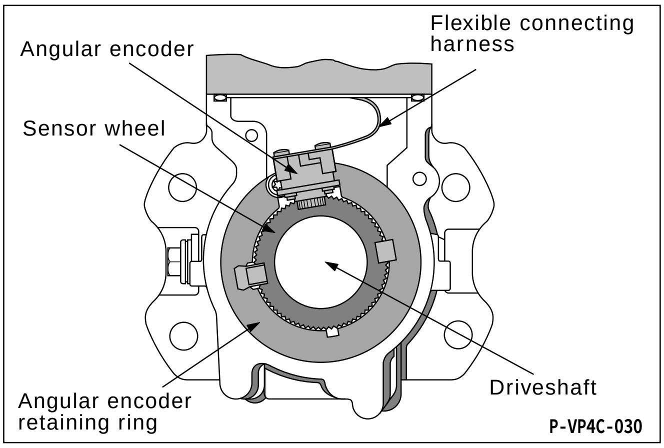
- The left hand figure shows an oblique view of the timer.
  The timer piston has a spring chamber balance port connecting the servo valve set spring chamber and the low pressure chamber. (This passage equalizes the pressure of the servo valve set spring chamber.)

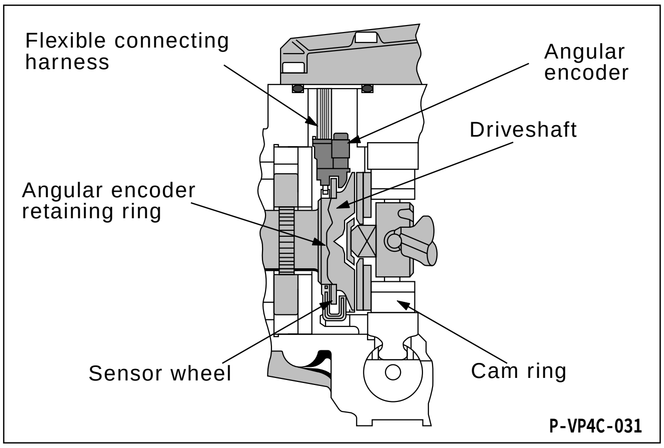


[10] TCV

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

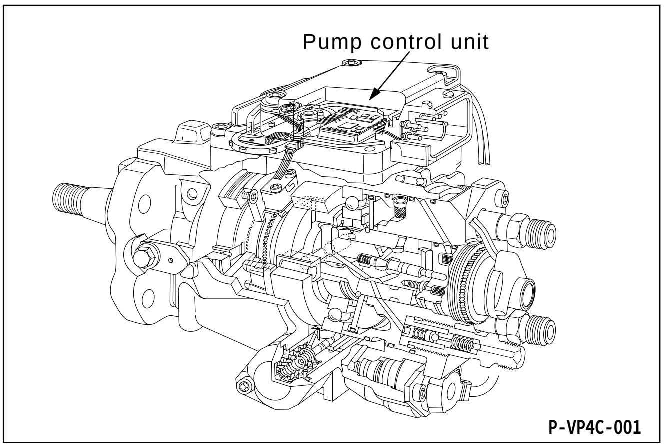






[11] Angular encoder

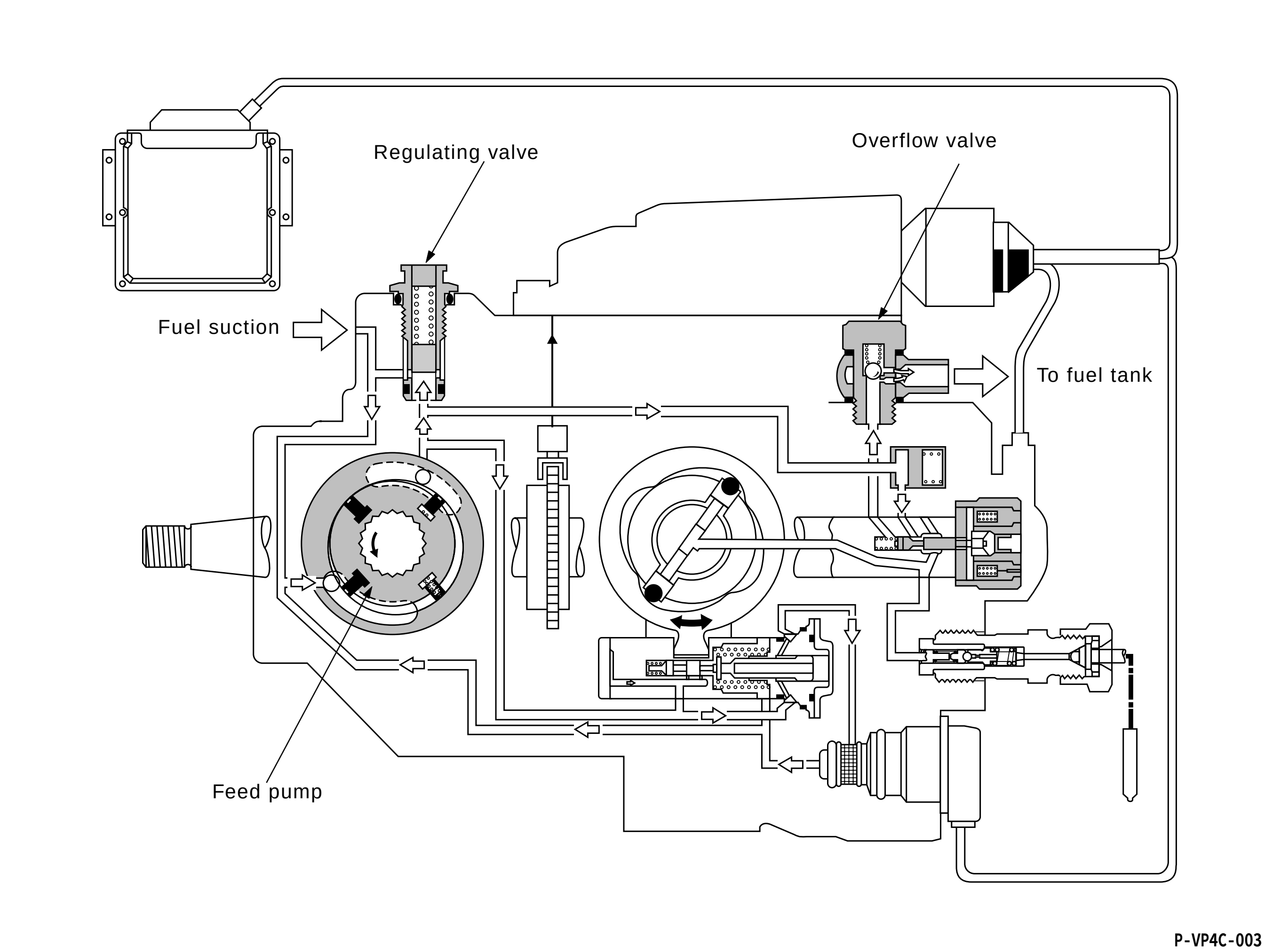
The angular encoder consists of a flexible connecting harness, the angular encoder itself, and the angular encoder retaining ring. A sensor wheel with precisely machined teeth is fixed to the driveshaft.
The sensor wheel has gaps in the teeth corresponding to the cylinder positions. These gaps are in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



[12] Pump control unit

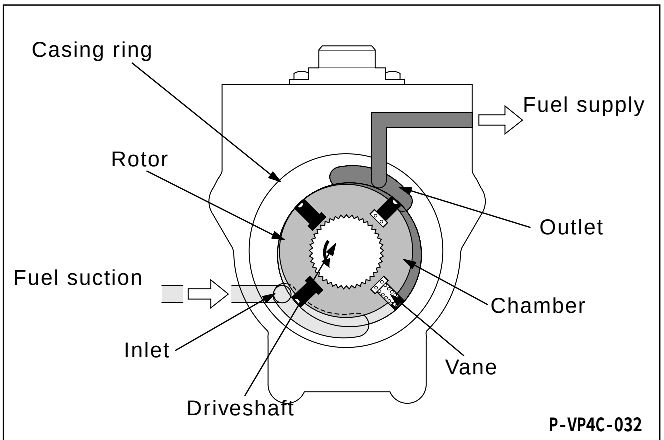
The pump control unit is installed directly on top of the injection pump and is equipped with a temperature sensor.
The pump control unit determines the drive signals for the TCV and the high pressure solenoid valve from information from the engine control unit.
The pump control unit receives signals from the angular encoder for injection pump speed and cam ring rotation and outputs TCV control signals, which are the basic timer drive signal values.
Fuel injection quantities predetermined in the engine control unit are converted to injection timing (time control) by the pump control unit and output as high pressure solenoid valve drive signals.
At this time fuel temperature is taken into consideration.
The bottom of the pump control unit is cooled by the fuel in the fuel injection pump.

1. LOW PRESSURE FUEL CIRCUIT



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.



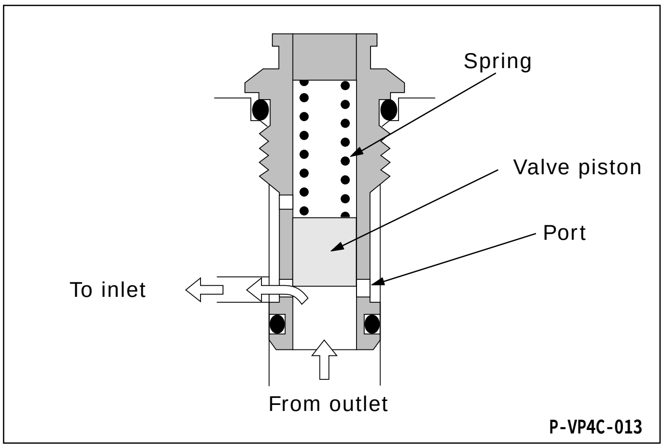
[1] Feed pump

The feed pump, driven by the driveshaft, performs suction and supply of fuel.

The vanes assembled in the rotor are pressed against the inside of the casing ring by spring force and centrifugal force during rotation to form chambers.

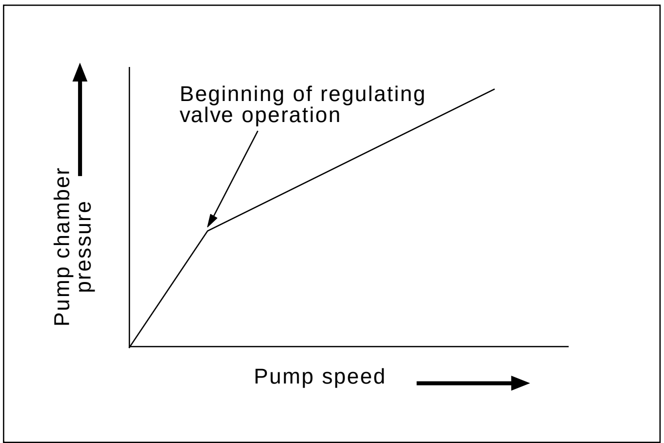
When the vanes rotate, the volume of these chambers increase when they reach recesses in the casing ring connected to the inlet port. Pressure then decreases and fuel is drawn in.

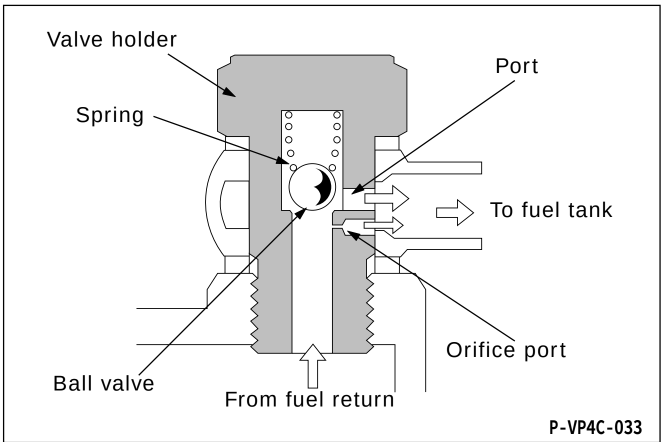
When the chambers have passed the inlets and recesses, the volume decreases and the fuel is compressed. Fuel pressure increases until the chamber reaches the outlet, where the fuel passes through the regulating valve to the high pressure fuel circuit.



[2] Regulating valve

When feed pump speed increases so that the delivery pressure of the fuel delivered from the outlet exceeds the regulating valve spring force, the valve piston is pushed up.
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 valve piston is pushed down by spring force to close the port.

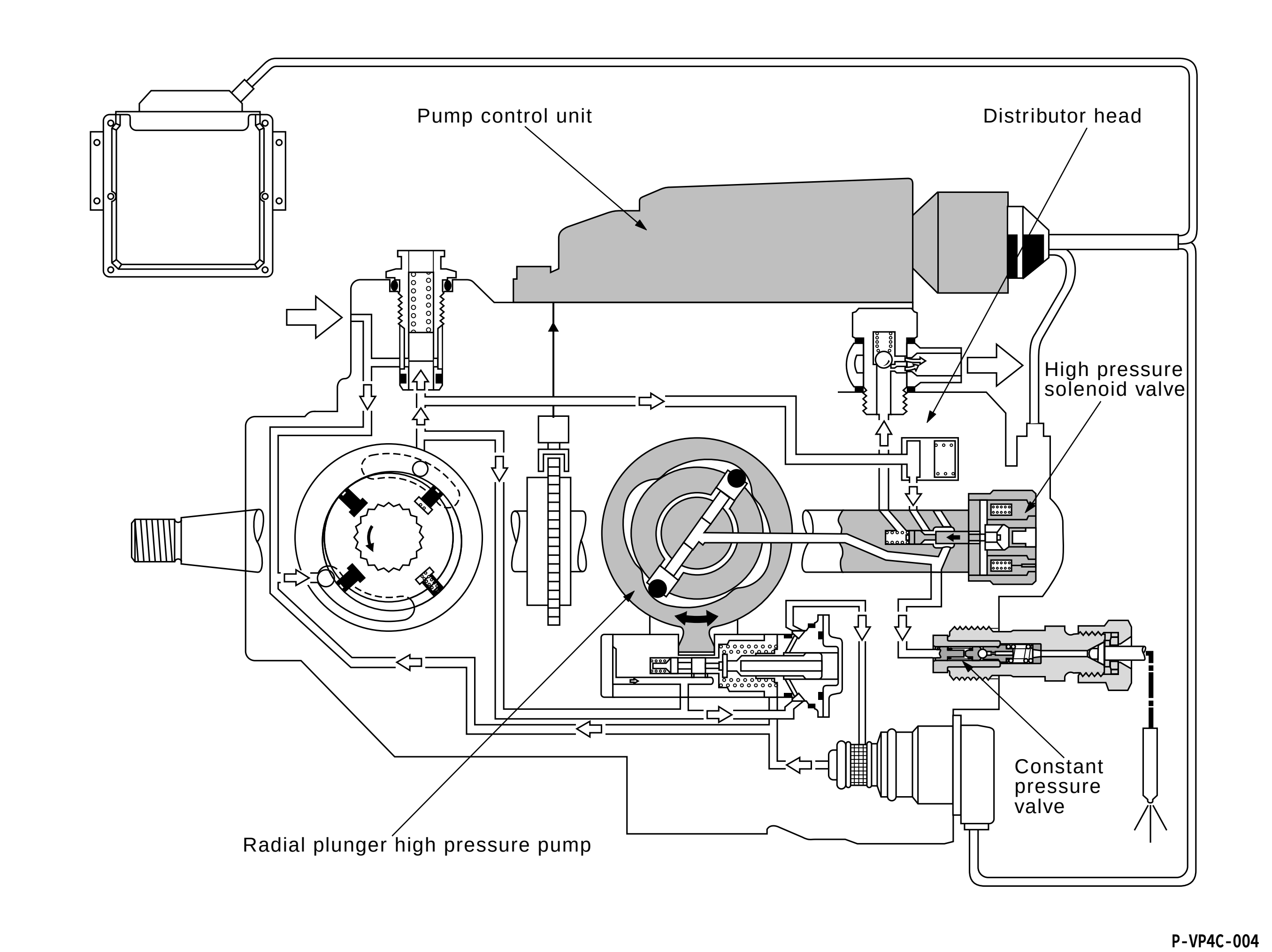




[3] Overflow valve

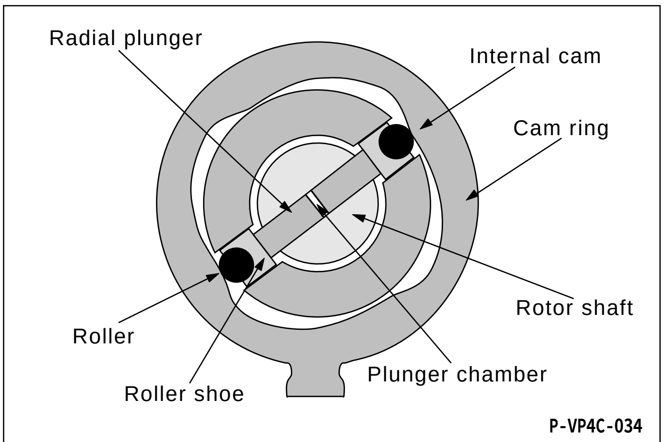
When the pressure of the fuel returned from the distributor head's fuel return exceeds the spring force, the overflow valve's ball valve is pushed up.
Excess fuel passes through the port and returns to the tank, and fuel pressure inside the pump chamber does not exceed a specified pressure.
By returning fuel to the tank to prevent the fuel from exceeding a specified pressure, the overflow valve also works to cool the injection pump and perform air bleeding.
The orifice port is installed to assist in automatic air bleeding.

2. HIGH PRESSURE FUEL CIRCUIT



In addition to a 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: Timer (TCV)
Prevention of secondary injection: Constant pressure valve

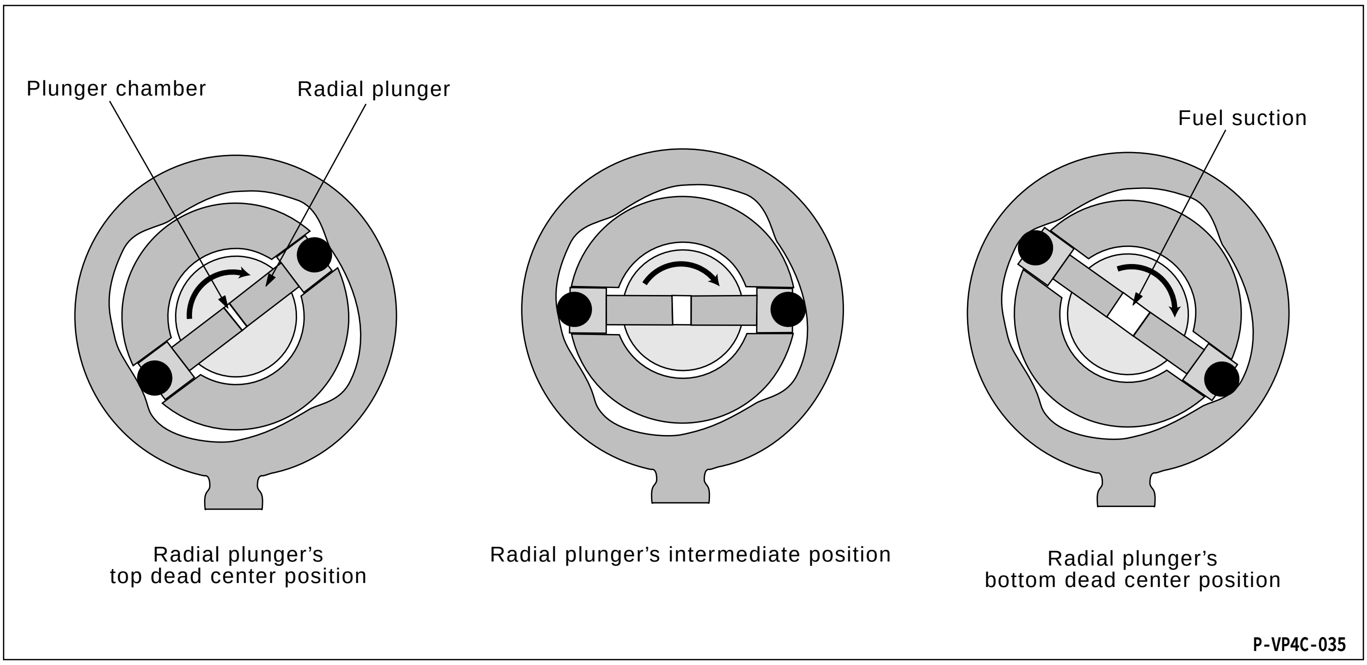


[1] Radial plunger high pressure pump

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.

3 OPERATION

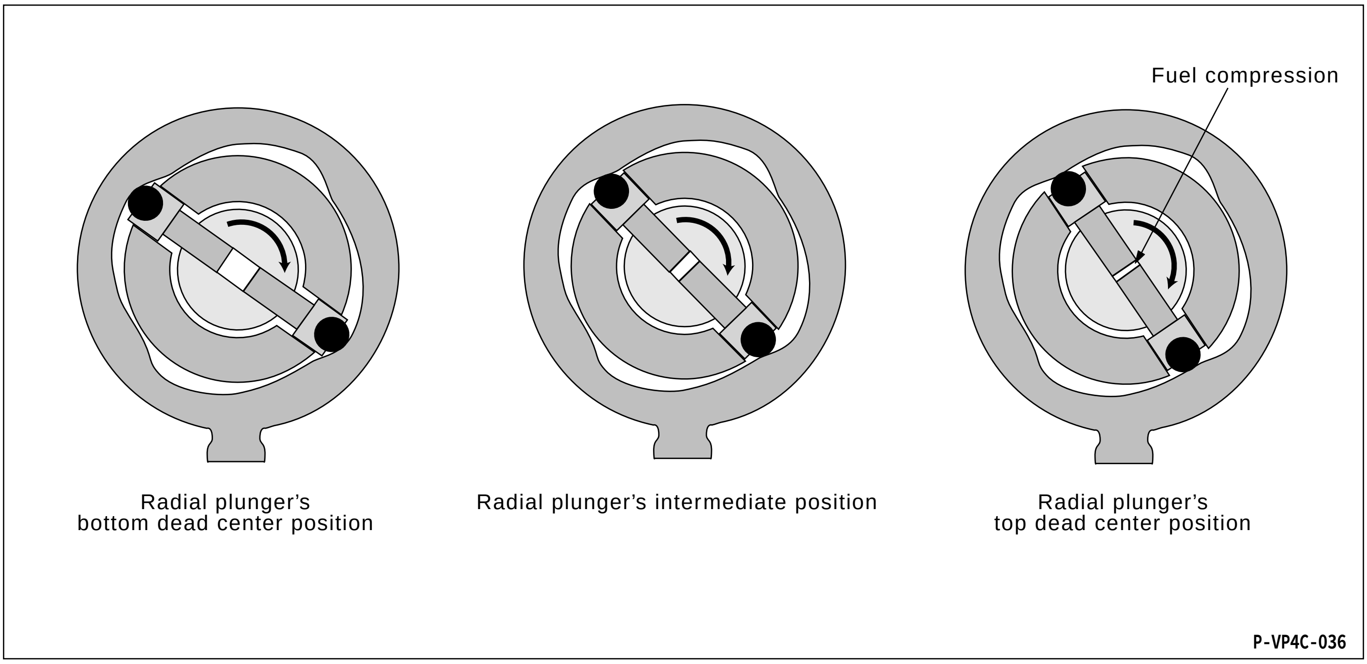
(1) Fuel suction



When the radial plungers rotate from the top dead center position the volume of the plunger chamber increases. Fuel is sucked in until the plungers reach the bottom dead center position.

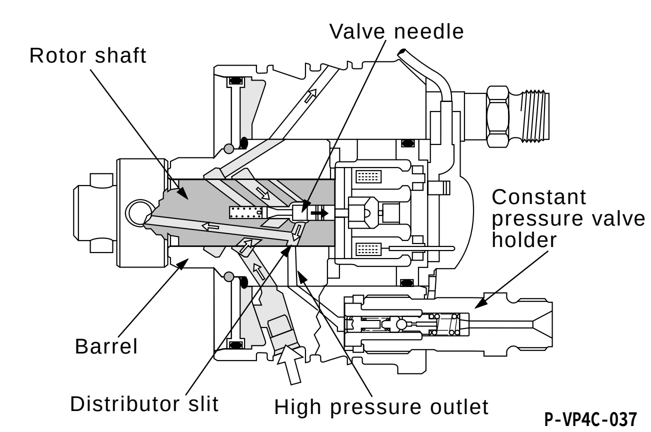
At fuel suction, the high pressure solenoid valve's valve needle seat is open (and the high pressure passage from the feed pump is open).

(2) Fuel compression



When the radial plungers rotate from the bottom dead center, they are pressed up by the cam ring's internal cams so that the volume of the plunger chamber decreases, and fuel is compressed until the plungers reach the top dead center.

At fuel injection the high pressure solenoid valve's valve needle seat is closed (and the high pressure passage from the feed pump is closed).

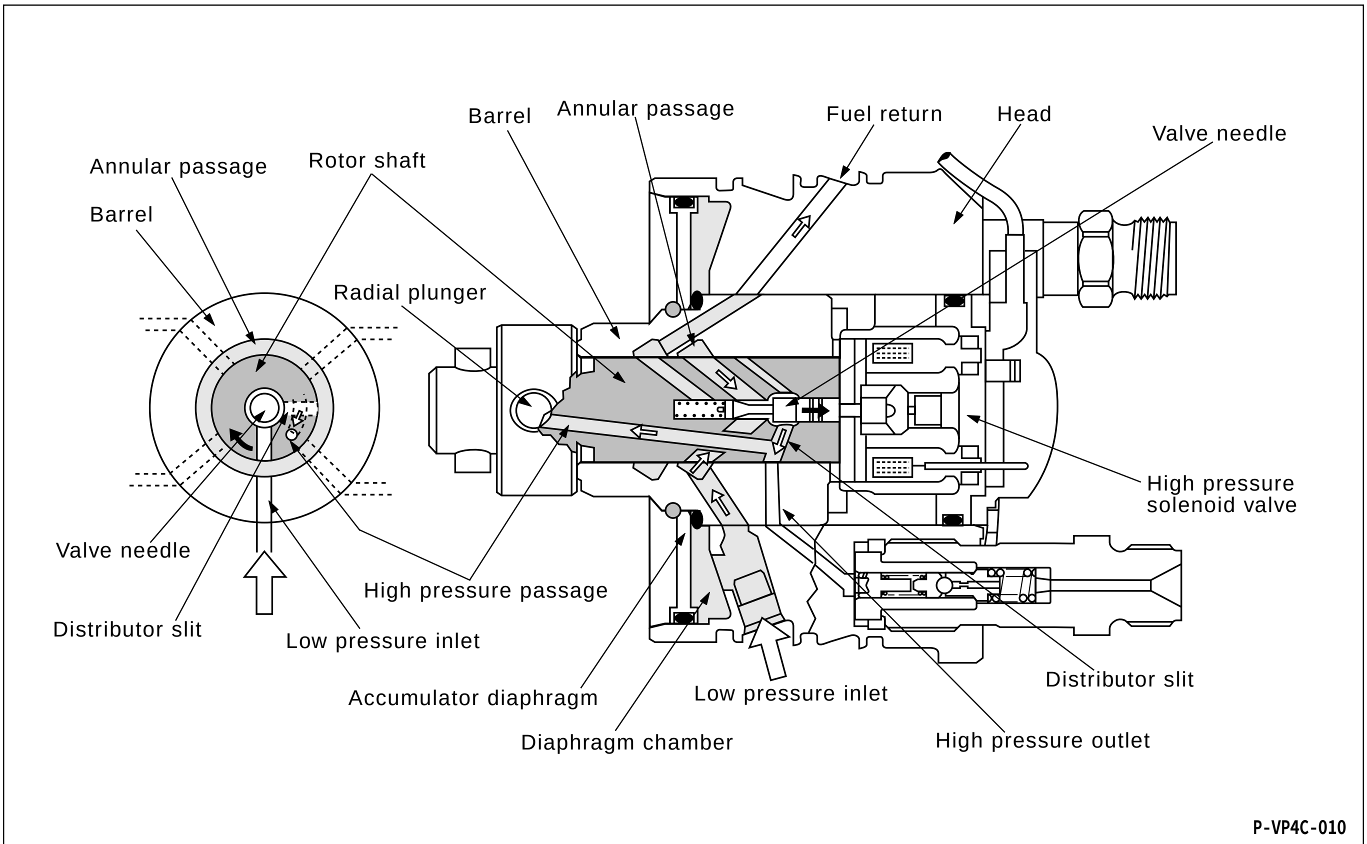


[2] Distributor head

The distributor head distributes 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; 6 cylinders: 6) to the engine cylinders through the constant pressure valve and the nozzle holder assemblies.

The high pressure solenoid valve's valve needle changes the passage to the radial plunger high pressure pump between fuel suction and fuel compression.

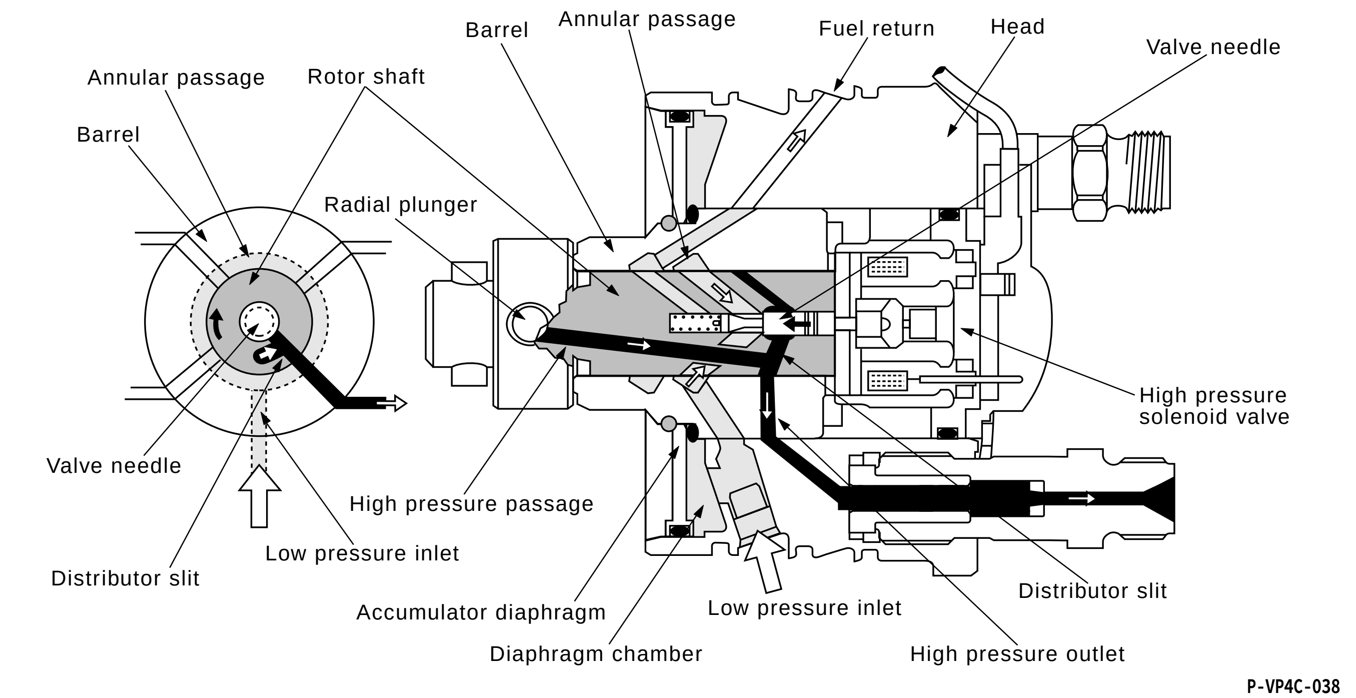
(1) Fuel suction process



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.

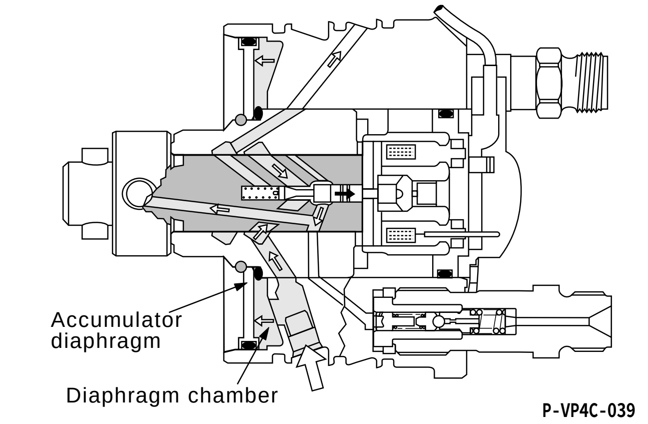
The radial plungers are pushed against the cam ring's inner cams by the fuel delivery pressure, the volume of the plunger chamber increases, and fuel suction is performed. At this time, the rotor shaft's distributor slits are not connected to the barrel's high pressure outlets.

(2) Fuel pressure delivery process



The radial plungers are pushed up by the cam ring's cams, the volume of the plunger chamber decreases and the fuel is compressed. At this time, the distributor slits are connected to the barrel's high pressure outlets by rotor shaft rotation.

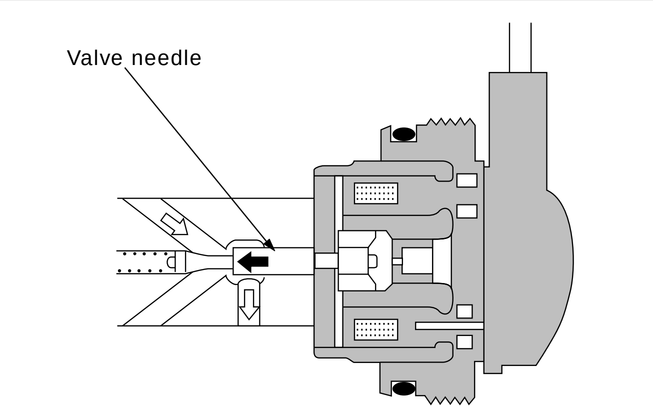
The high pressure fuel is then delivered through the high pressure passage, the distributor slits and the high pressure outlets, and then through the constant pressure valve to the nozzle holder assembly.



(3) End of fuel pressure delivery

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 pressure feed fuel until they reach the cams' top dead centers. The excess fuel flows through the passage until it reaches the diaphragm chamber. At this time the pressure of the high pressure fuel flowing back through the low pressure circuit is decreased by the accumulator diaphragm, and is simultaneously accumulated in preparation for the next injection.

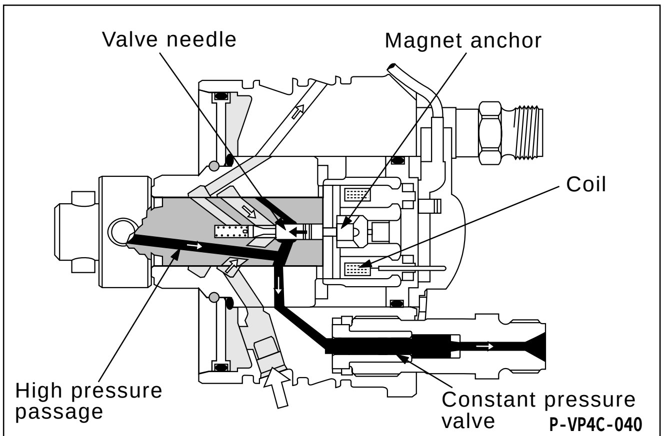


P-VP4C-022

[3] High pressure solenoid valve

The high pressure solenoid valve has a valve needle, and this valve needle is opened and closed by the control current from the pump control unit.

This results in the switching of the fuel outflow passage to control fuel injection quantity.

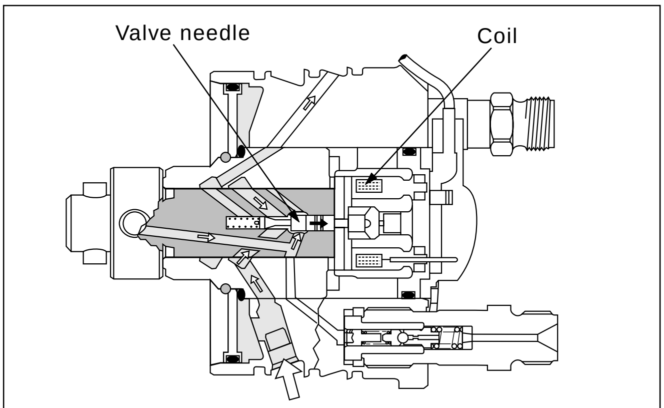


P-VP4C-040

(1) Beginning of injection

When control current from the pump control unit flows to the high pressure solenoid valve coil, the magnet anchor (a movable iron core) is pushed, together with the valve needle, towards the valve seat. When the valve seat is completely closed by the valve needle, the path of the fuel in the high pressure passage to the low pressure circuit is cut.

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 to the nozzle holder assembly and is injected into the engine cylinder.

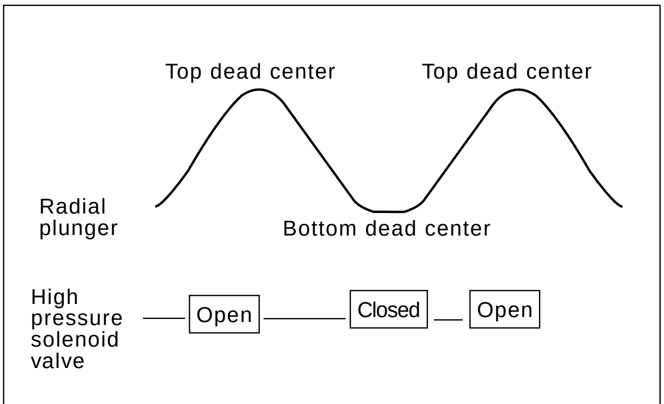


P-VP4C-041

(2) End of injection

When the fuel injection quantity demanded by the engine is reached, the current to the coil is cut and the valve seat is reopened by the valve needle. 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 fuel injection to the engine ends.

To accurately control this process, the control unit determines the actual closing point of the high pressure solenoid valve.

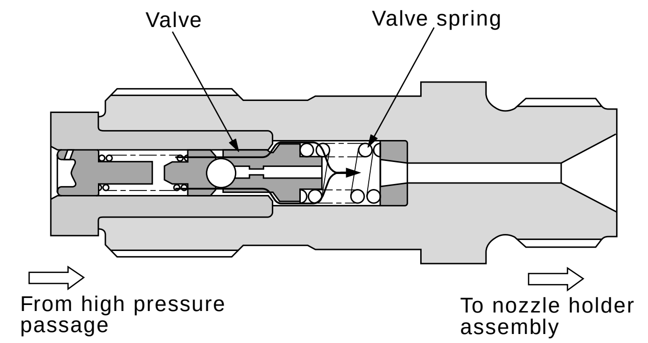


P-VP4C-042

[4] Constant pressure valve (CPV)

The constant pressure valve decreases the reverse pressure wave (ie, the reflected wave) generated at nozzle valve closing to prevent the nozzle from reopening (ie, secondary injection).

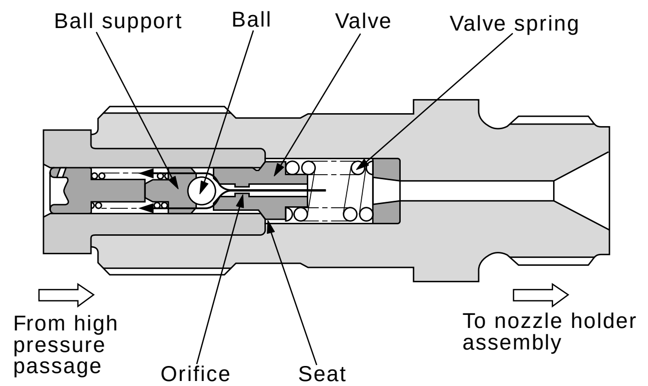
Also, the constant pressure valve suppresses the generation of cavitation in the high pressure pipe, which is the cause of pipe erosion, and also maintains a stable pressure in the injection pipe (residual pressure) to ensure stabilized beginning of injection timing for subsequent injection.



P-VP4C-043

(1) Beginning of delivery

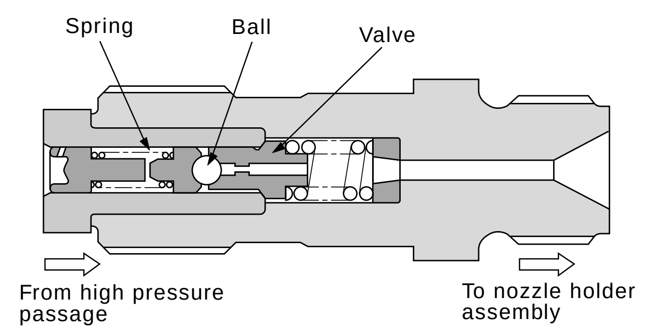
The radial plunger compresses the fuel in the plunger chamber. When the pressure of the fuel delivered to the CPV overcomes the residual pressure in the injection pipe and the valve spring set force, the valve is pushed up and the fuel is delivered to the nozzle holder assembly (beginning of fuel delivery).



P-VP4C-044

(2) End of delivery

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

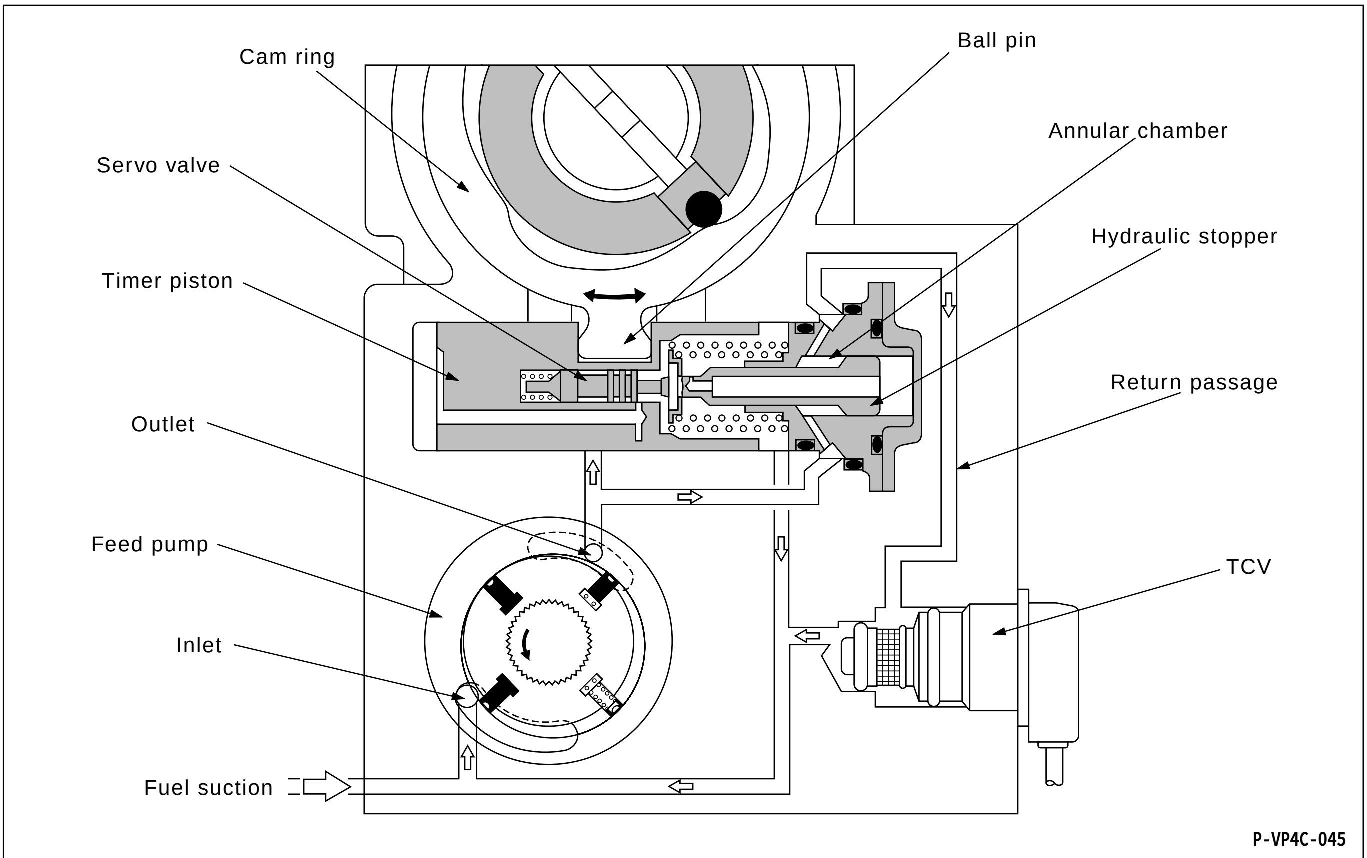


P-VP4C-018

- 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.

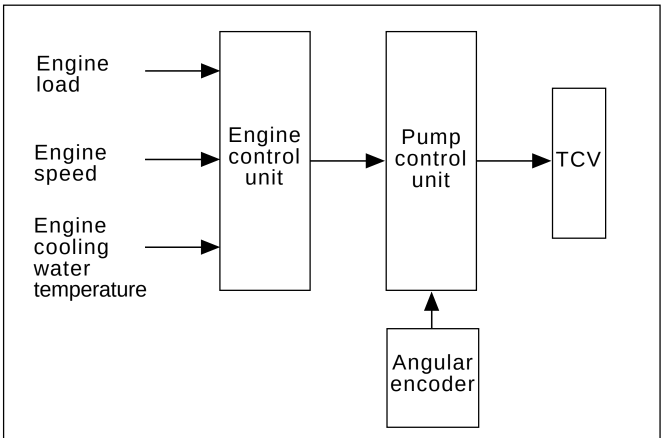
3. TIMING CONTROL

[1] Timer operation



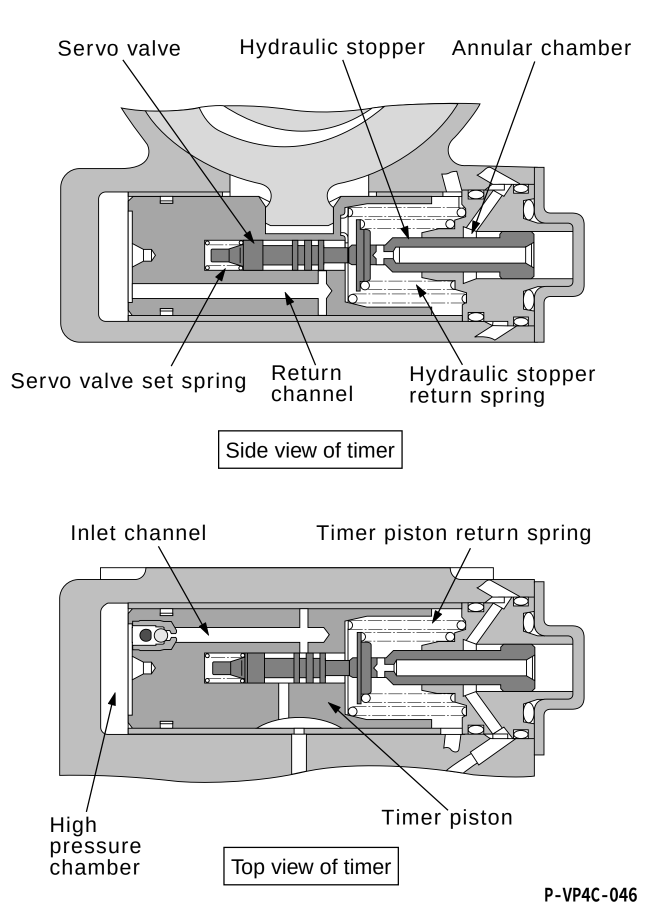
The timer determines the optimum injection timing against variations in engine speed.
The pressure of the fuel fed from the feed pump is adjusted in accordance with speed by the regulating valve. This delivery pressure acts on the hydraulic stopper's annular chamber as control pressure. The chamber pressure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

The timer is connected to the radial plunger high pressure pump's cam ring by a ball pin, and axial timer piston movement is transferred to the cam ring in the form of rotational movement.
Timer piston movement to the right (to the spring side) advances injection timing.
The main components are the timer, the TCV and the angular encoder.



(1) Beginning of injection setting

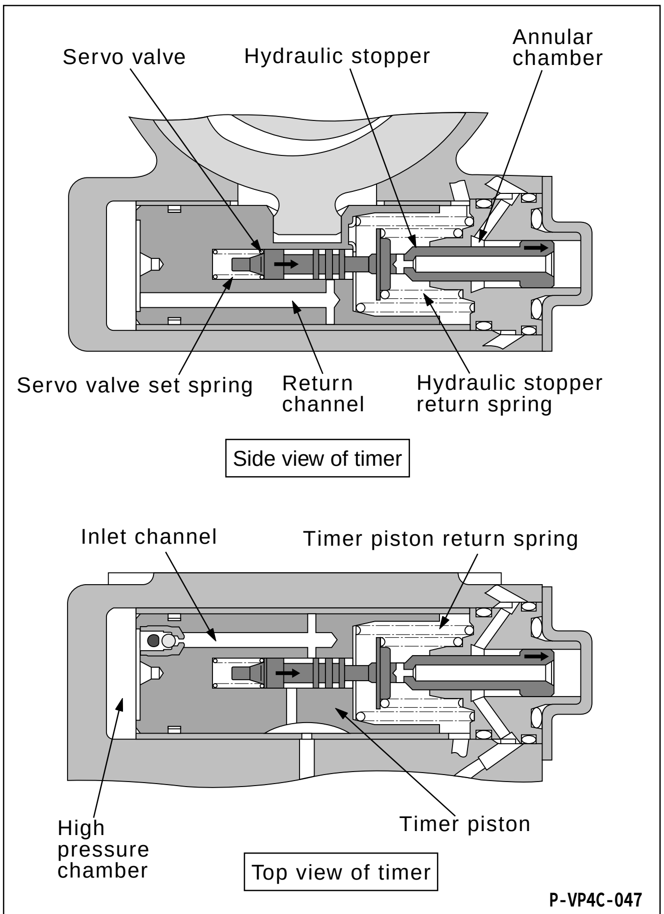
The engine control unit contains predetermined beginning of injection characteristic maps corresponding to engine operating conditions (engine load, speed and cooling water temperature).
The pump control unit is constantly comparing the set beginning of injection timing and the actual beginning of injection timing. If there is a difference, the TCV is controlled by the duty ratio. (The actual beginning of injection timing is determined from the angular encoder signal.)



(2) When the annular chamber pressure is low (advance angle 0)

When the pressure of the annular chamber is less then 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 (ie, the inlet channel) is cut. The timer piston is held on the left hand side (ie, the retard side) by the timer piston return spring.

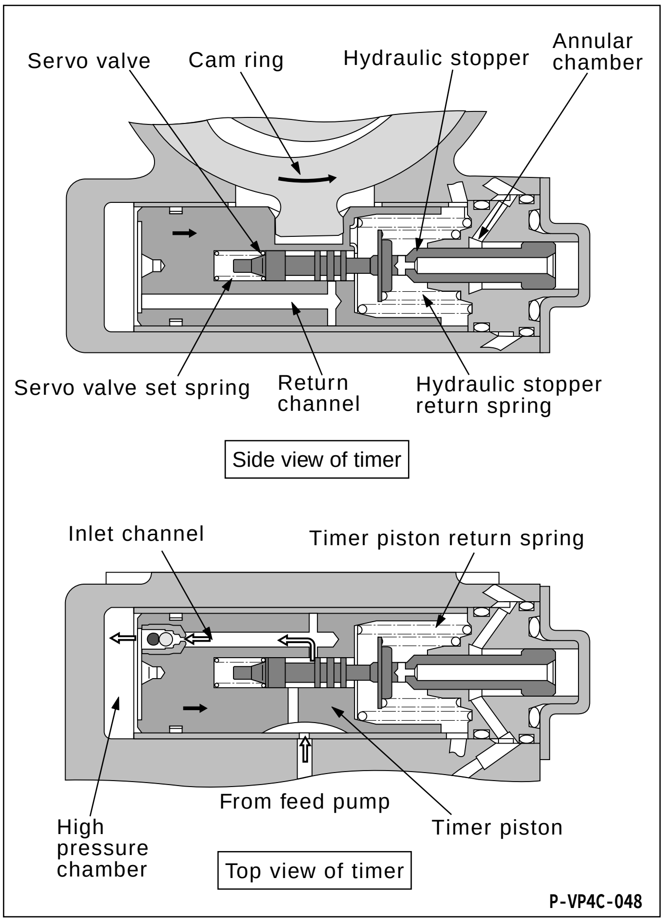
Return channel	Open
Inlet channel	Closed



(3) When the annular chamber pressure has increased (advance)

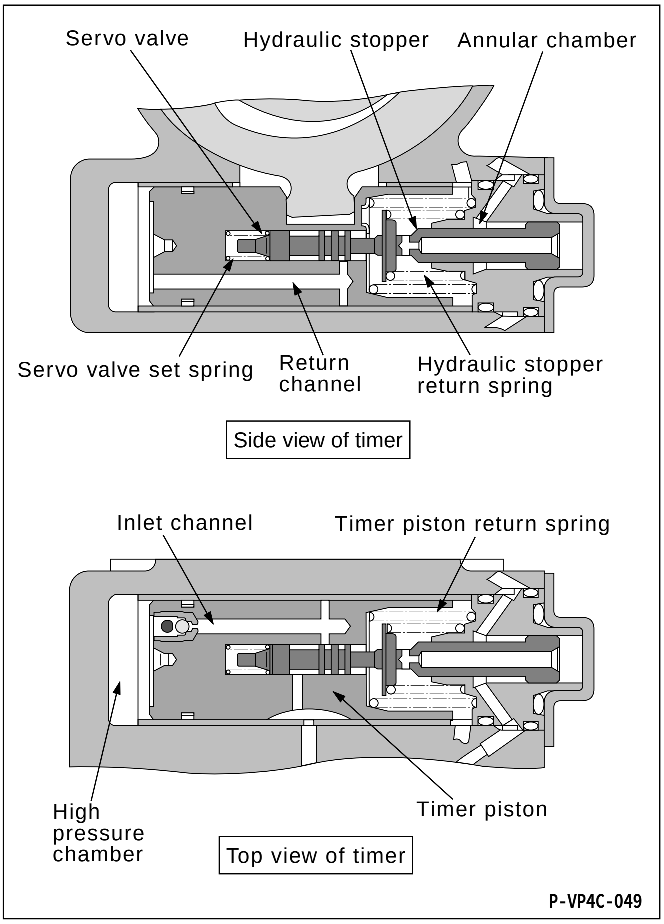
- When the annular chamber pressure increases and exceeds the force of the hydraulic stopper return spring, the hydraulic stopper is moved to the right (ie, in the advance direction).
  Consequently, the servo valve is also moved to the right by the servo valve set spring and the inlet channel to the timer's high pressure chamber is opened.

Return channel	Closed
Inlet channel	Open



- 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 (ie, in the advance direction) and the cam ring is turned in the advance direction. Consequently, the cam ring's cams advance the radial plungers' beginning of compression interval to bring about an advance in the beginning of injection.
  A maximum timer advance angle position of 15 cam angle degrees (equivalent to 30 crankshaft degrees) is possible.

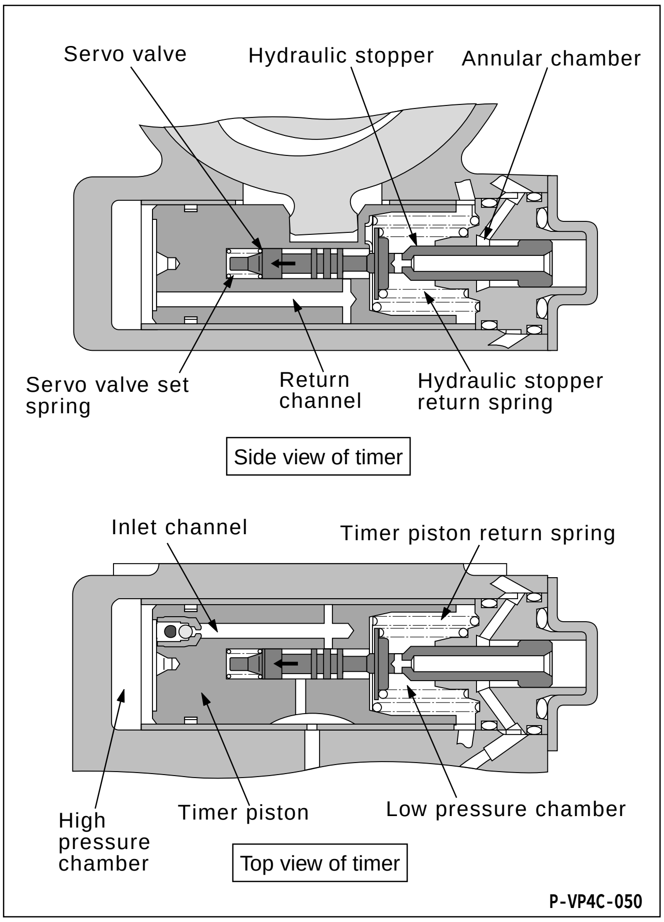
Return channel	Closed
Inlet channel	Open



(4) Stable condition

- 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.

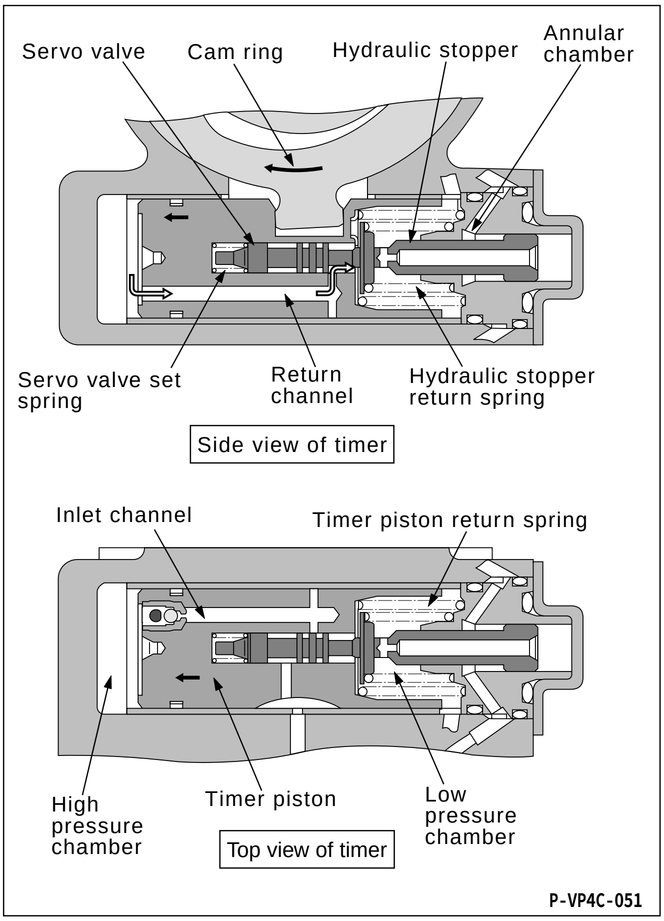
Return channel	Closed
Inlet channel	Closed



(5) When annular chamber pressure has decreased (at timing retard)

- The TCV, in response to pump control unit 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, and 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 (ie, in the retard direction) until the set forces of the hydraulic stopper return spring and the servo valve set spring balance the annular chamber pressure.
  Consequently, the return channel connecting the timer's high pressure chamber to the low pressure chamber is opened.

Return channel	Open
Inlet channel	Closed

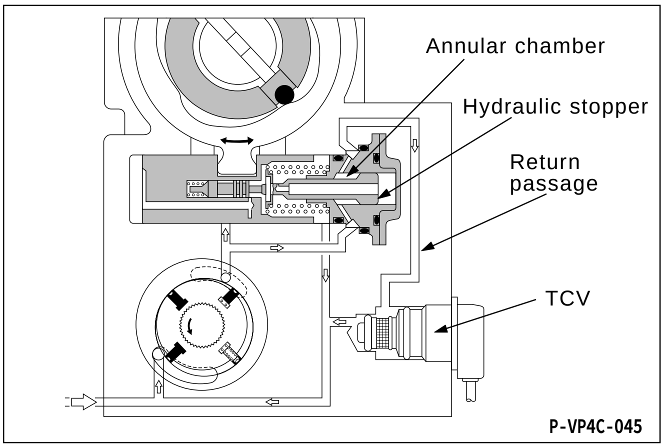


- The fuel in the timer's high pressure chamber flows through the return channel to return to the low pressure chamber.
  Because of the decrease in the high pressure chamber pressure, the timer piston is moved to the left (ie, in the retard direction) by the timer piston return spring, and the cam ring is rotated in the retard direction.
  Consequently, the cam ring's cams retard the radial plungers' beginning of compression interval to retard the beginning of injection.

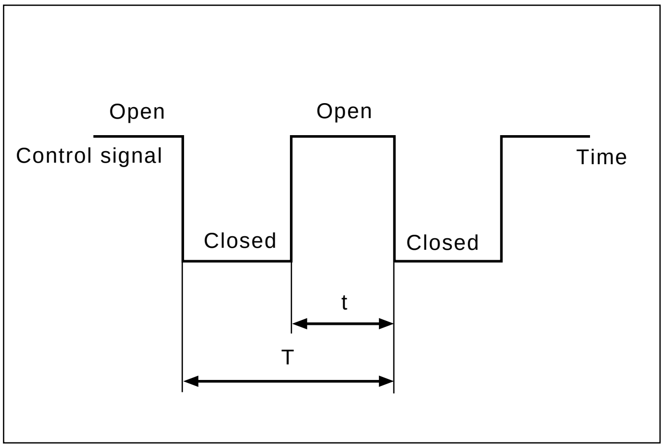
Return channel	Open
Inlet channel	Closed

- 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 chamber 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 balanced (ie, in a stabilized condition).

[2] TCV operation



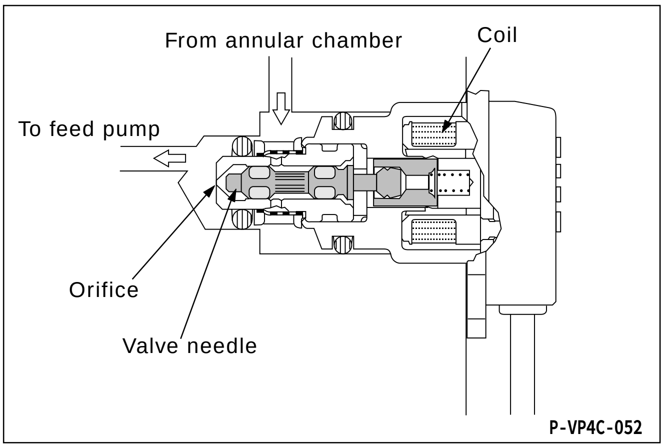
- The TCV acts as a variable throttle, using the rapid opening and closing (cycling) of the valve needle in the TCV.
  At normal operation, the TCV influences control pressure acting on the annular chamber so that the hydraulic stopper can be freely set in any position, from the retard position to the advance position. At this time, the duty ratio is set by the pump's control unit.



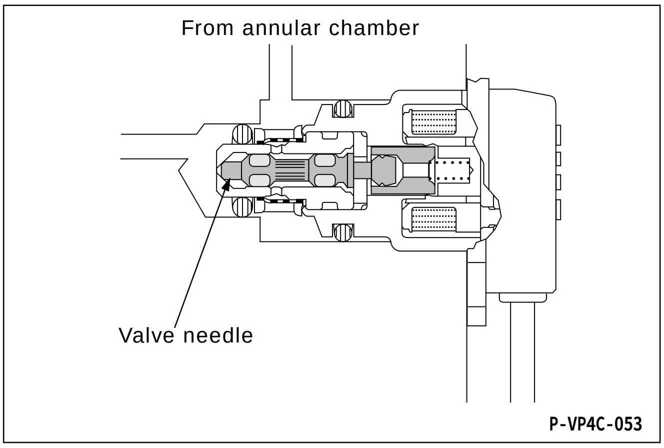
- Duty ratio is the ratio of the time that the TCV is open to one complete TCV operating cycle. (A duty ratio change of 100% to 0% is an advance in injection timing.)

Duty ratio = t / T x 100%

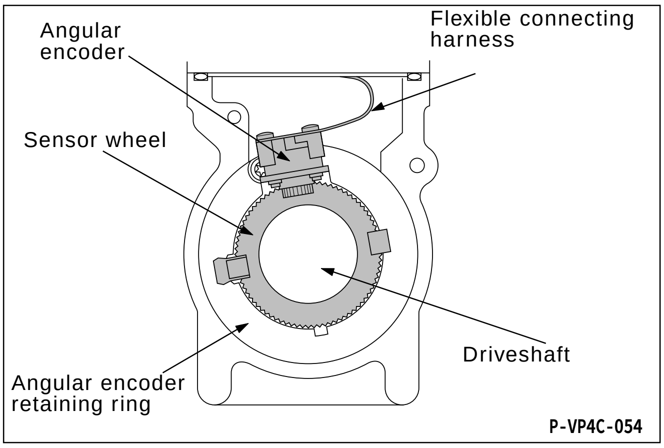
Note:
COVEC-F displays an OFF duty ratio, while the VP44 displays an ON duty ratio.

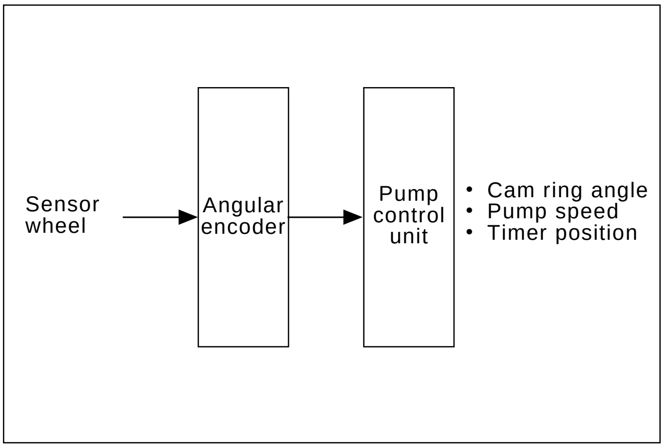


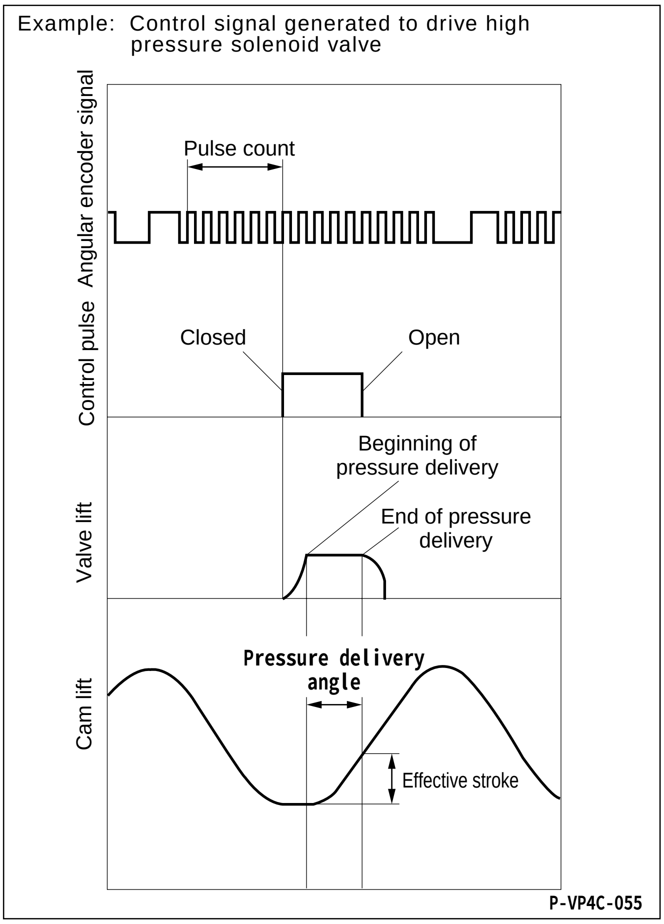
- When control current flows to the TCV coil, the valve needle opens and the fuel in the annular chamber flows through the orifice to the feed pump inlet. Consequently, the pressure of the annular chamber decreases and the hydraulic stopper is moved to the retard side.



- When control current to the 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.







4. ANGULAR ENCODER

When the driveshaft rotates, the angular encoder receives signals from the sensor wheel teeth, and an electric pulse is sent through the flexible connecting harness to the pump control unit.

From these signals the pump control unit can determine the average pump speed and the momentary pump speed.

The angular encoder is mounted on a retaining ring, which can rotate and is connected to the cam ring.

Thus, the relationship between the cam ring cams and the angular encoder signal is constant.

The angular encoder 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 timer position

(1) Momentary cam ring angular position

The momentary angular position of the cam ring is input into the pump control unit 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.

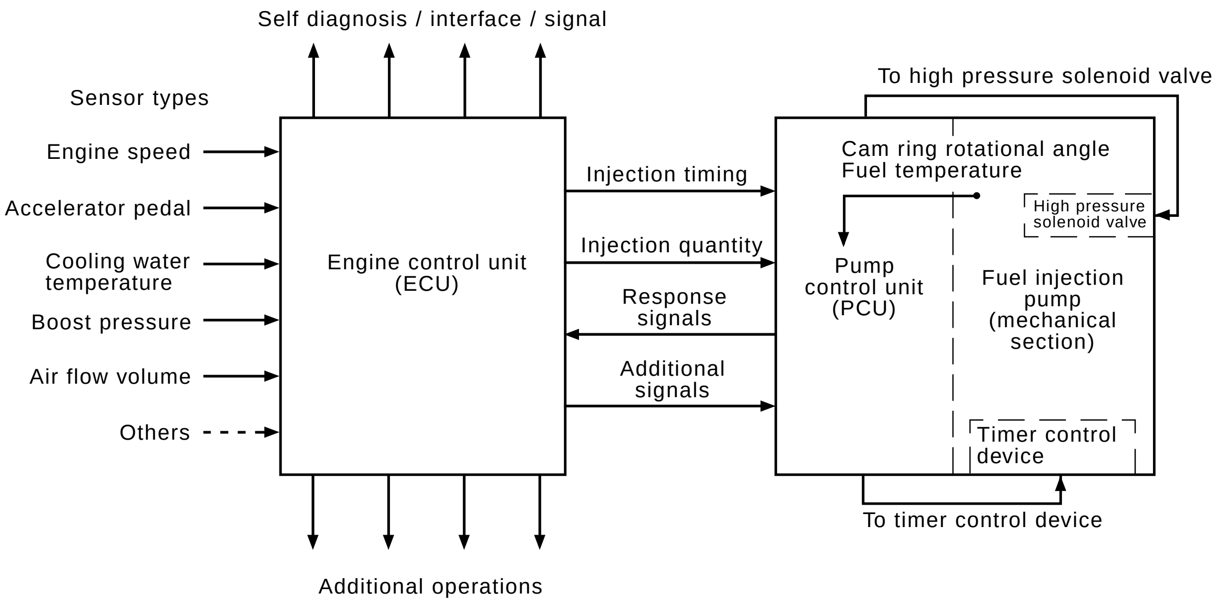
(2) Actual injection pump speed

When the crankshaft speed sensor is faulty, the injection pump speed signal serves as a spare engine control unit signal.

(3) Actual timer position

The actual timer position can be determined by comparing the crankshaft speed sensor signal with the angular encoder angle. This position is used for timer control.

5. PUMP CONTROL UNIT



The radial plunger distributor type fuel injection pump has two electronic control devices: the pump control unit and the engine control unit.

The pump control unit receives signals from the sensors inside the pump for cam ring rotation angle and fuel temperature to determine engine control unit set values, as well as injection timing and fuel injection quantity. The engine control unit processes all engine data and data regarding the surrounding environment received from external sensors to perform any engine side adjustments.

Maps for the above are encoded in both control units.

The control units' input circuits process sensor data. A microprocessor then determines operating conditions and calculates set signals for optimum running.

The interchange of data between the engine control unit and the pump control unit is performed via a bus system (CAN: controller area network).

By having two separate control units, the high pressure solenoid valve's drive circuit can be located near the solenoid valve to prevent the discharge of any disturbing signals.

Pub. No: EE14E-11130

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