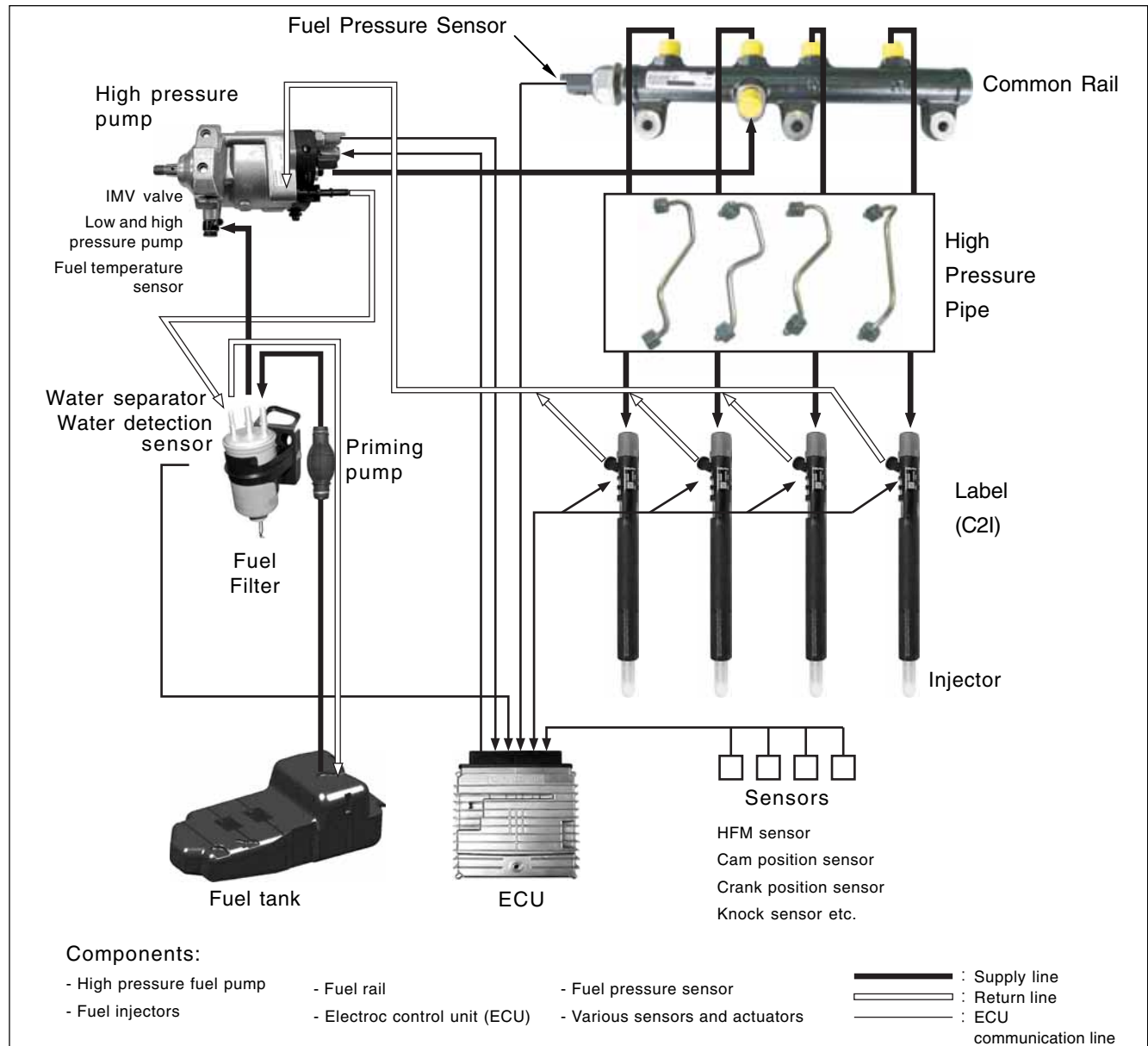


FUEL SYSTEM

FUEL INJECTION SYSTEM

► Electronic Control of Fuel System



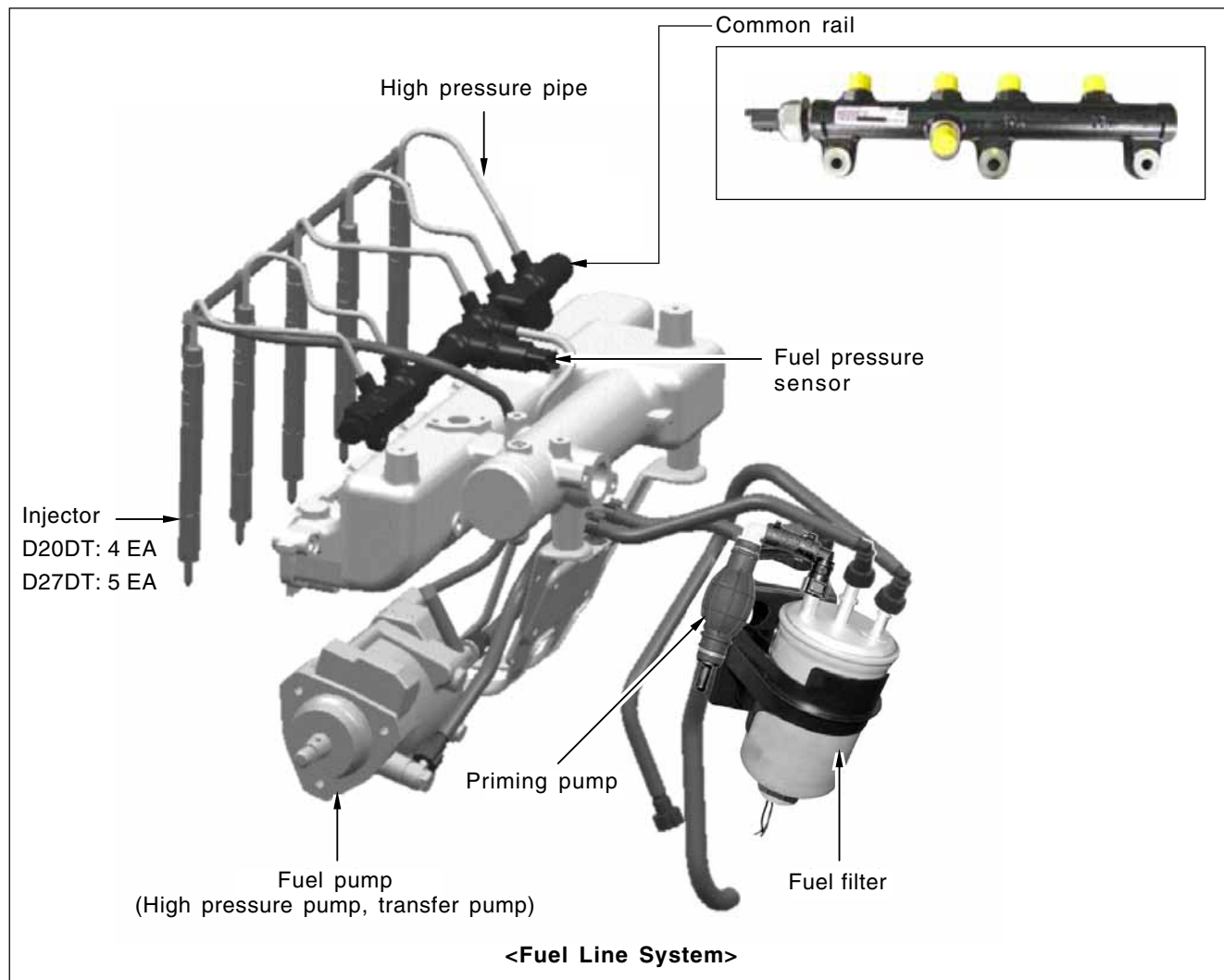
According to input signals from various sensors, engine ECU calculates driver's demand (position of the accelerator pedal) and then controls overall operating performance of engine and vehicle on that time.

ECU receives signals from sensors via data line and then performs effective engine air-fuel ratio controls based on those signals. Engine speed is measured by crankshaft speed (position) sensor and camshaft speed (position) sensor determines injection order and ECU detects driver's pedal position (driver's demand) through electrical signal that is generated by variable resistance changes in accelerator pedal sensor. Air flow (hot film) sensor detects intake air volume and sends the signals to ECU. Especially, the engine ECU controls the air-fuel ratio by recognizing instant air volume changes from air flow sensor to decrease the emissions (EGR valve control). Furthermore, ECU uses signals from coolant temperature sensor and air temperature sensor, booster pressure sensor and atmospheric pressure sensor as compensation signal to respond to injection starting, pilot injection set values, various operations and variables.

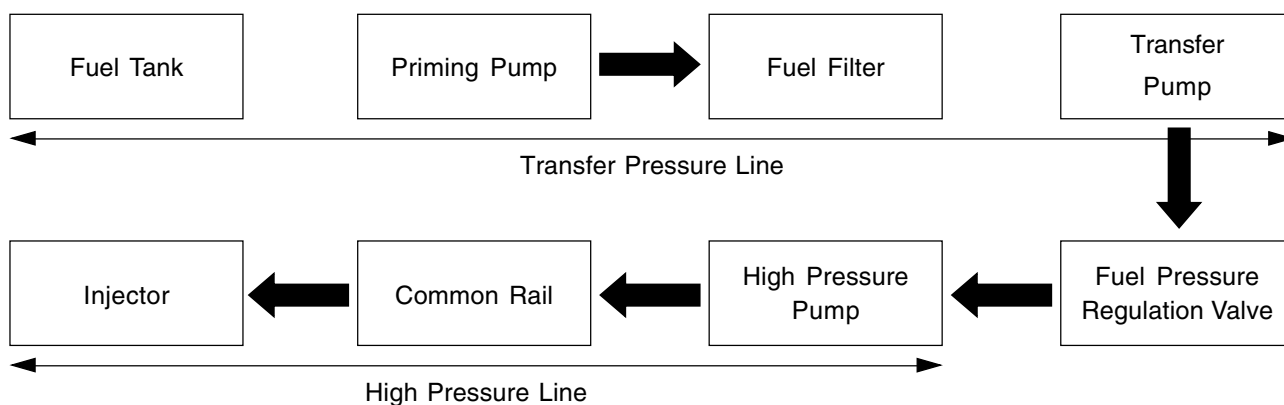
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► Composition of Fuel System

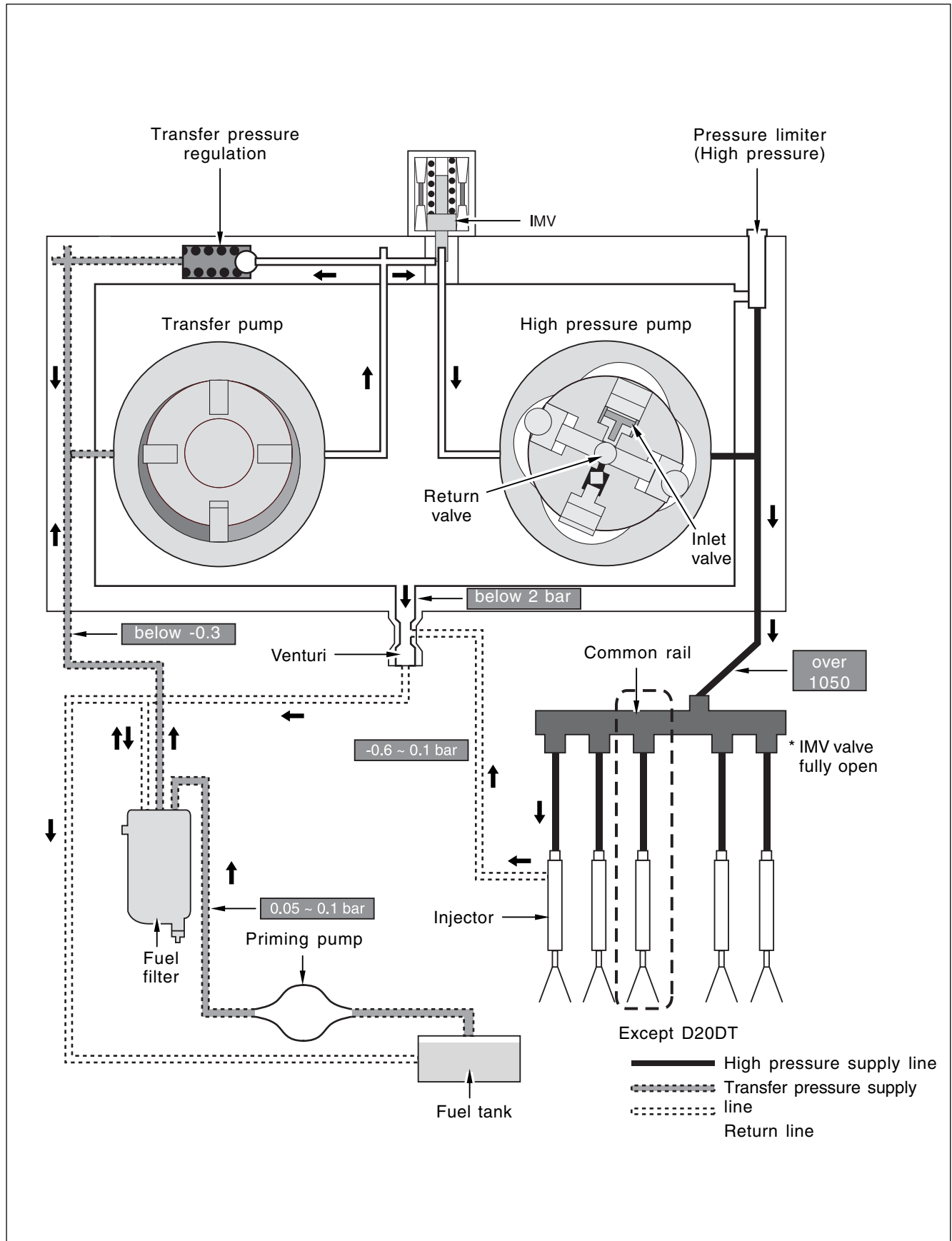
Components in fuel system are designed to generate and distribute high pressure, and they are controlled electronically by engine ECU. Accordingly, fuel system is completely different from injection pump type fuel supply system on the conventional Diesel engine. The fuel injection system in common rail engine is composed of transfer pressure section that transfers fuel in low pressure, high pressure section that transfers fuel in high pressure and ECU control section.



Fuel route



► Hydranlic Cycle in Fuel Line (Transfer and High Pressure Line)



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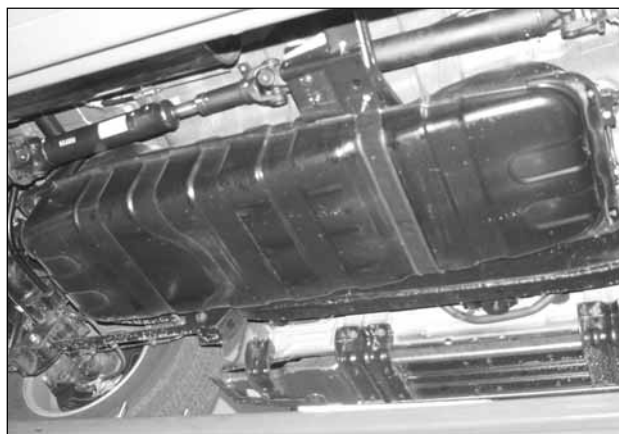
► Components of Low Pressure Transfer Line

Low pressure stage is to supply sufficient fuel to high pressure section and components are as below.

1. Fuel tank (including strainer)
2. Hand priming pump
3. Fuel filter
4. Transfer pump
5. Other low pressure fuel hoses

Fuel tank

Fuel tank is made of anti-corrosion material and its allowable pressure is 2 times of operating pressure (more than min. 0.3 bar). It has protective cap and safety valve to prevent excessive pressure building. Also, to supply fuel smoothly, it has structure to prevent fuel from leaking in shocks, slopes and corners and.



Priming pump

If fuel runs out during driving or air gets into fuel line after fuel filter replacement, it may cause poor engine starting or damage to each component. Therefore, the hand priming pump is installed to bleed air from transfer line.

When the vehicle is under the conditions as below, press the priming pump until it becomes rigid before starting the engine.

1. After run out of fuel
2. After draining the water from fuel separator
3. After replacing the fuel filter

Press the priming pump until it becomes rigid before starting the engine.



Fuel filter

It requires more purified fuel supply than conventional diesel engine. If there are foreign materials in the fuel, fuel system including pump components, delivery valve and injector nozzles may be damaged.

Fuel filter purifies fuel before it reaches to high pressure pump to help proper operations in high pressure pump. And more, it separates water from fuel to prevent water from getting into FIE system (high pressure line).



► Components of High Pressure Transfer Line

In the high pressure section, sufficient fuel pressure that injectors requires will be generated and stored. The components are as below:

1. High pressure pump
2. Rail pressure sensor
3. Pressure limit valve
4. Common rail
5. High pressure pipe
6. Injector
7. Fuel pressure regulating valve (IMV)

High pressure pump

This is plunger pump that generates high pressure; and driven by crankshaft with timing chain. The high pressure pump increases system pressure of fuel to approx. 1,600 bar and this compressed fuel is transferred to high pressure accumulator (common rail) in tube through high pressure line.



Common rail

It stores fuel transferred from high pressure pump and also stores actual high pressure of fuel. Even though the injectors inject fuel from the rail, the fuel pressure in the rail is maintained to a specific value. It is because the effect of accumulator is increased by unique elasticity of fuel. Fuel pressure is measured by rail pressure sensor. And the fuel pressure regulating valve (IMV, Inlet Metering Valve) included in high pressure pump housing keeps pressure to a desired level.



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High pressure pipe (fuel pipe)

Fuel line transfers high pressure fuel. Accordingly, it is made of steel to endure intermittent high frequency pressure changes that occur under maximum system pressure and injection stops. Injection lines between rail and injectors are all in the same length; it means the lengths between the rail and each injector are the same and the differences in length are compensated by each bending.



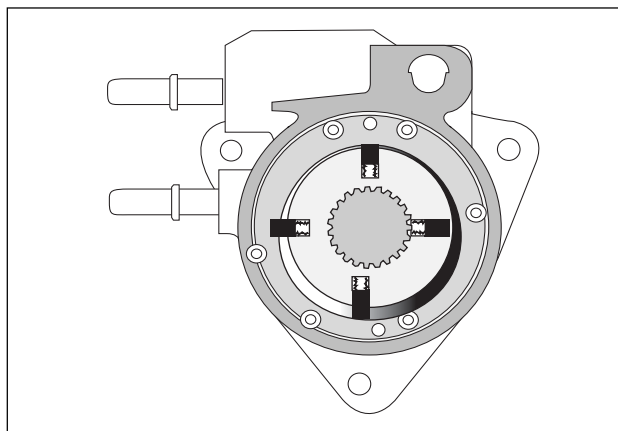
Injectors

The fuel injection device is composed of electrical solenoid valve, needle and nozzle and controlled by engine ECU. The injector nozzle opens when solenoid valve is activated to directly inject the fuel into combustion chamber in engine. When injector nozzle is open, remaining fuel after injection returns to fuel tank through return line. Pressure limit valve, fuel returned by low pressure and fuel used for high pressure pump lubrication also return to fuel tank through return line.



Transfer pump

The transfer pump is included in the housing of the high pressure pump. The transfer pump is the volumetric blade type pump. To deliver the continuously required fuel volume, the pump transfers fuel from the fuel tank to high pressure pump.



Fuel filter replacement

1. Fuel filter change interval: every 30,000 km
2. Water separation interval: every 10,000 km (same with engine oil change interval)
3. Never reuse the removed fuel filter

FUEL TRANSFER LINE

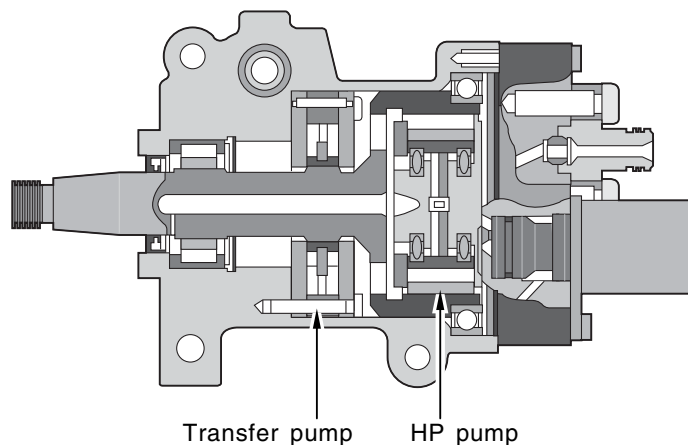
► Transfer Pump

Description

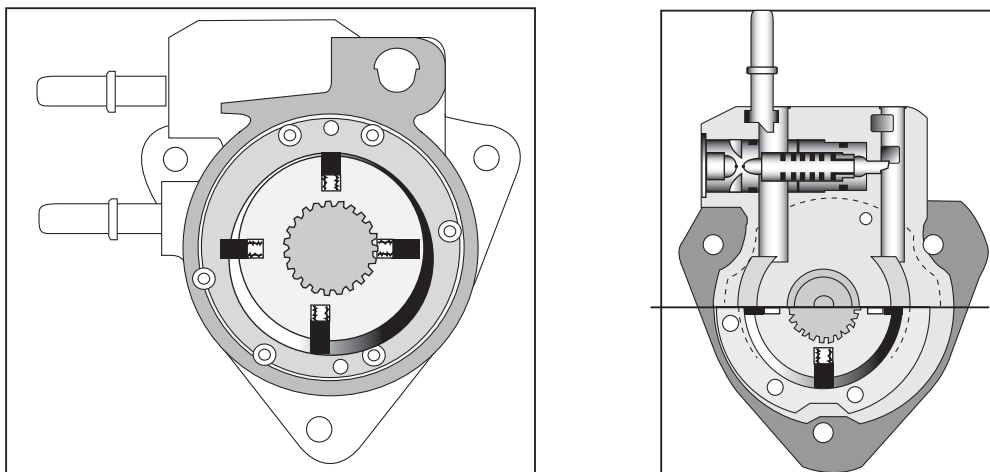
The transfer pump is the device to provide sufficient fuel to high fuel pressure line and is mechanical type feed pump that is driven by timing chain linked to crankshaft. This mechanical type feed pump is subject to air inflow, therefore, a hand priming pump is installed to bleed air from fuel transfer line.

The transfer pump is included in the housing of the HP pump. The transfer pump is the volumetric blade type pump and consists of the following components:

1. A rotor turned by the shaft of the HP pump. The connection is provided by splines.
2. An eccentric liner fixed to the housing of the HP pump by 6 Torx bolts. The liner is positioned by two off-set pins in order to prevent any assembly errors.
3. Four blades set at 90°. Each blade is held against the liner by a coil spring.
4. The inlet and outlet orifice.



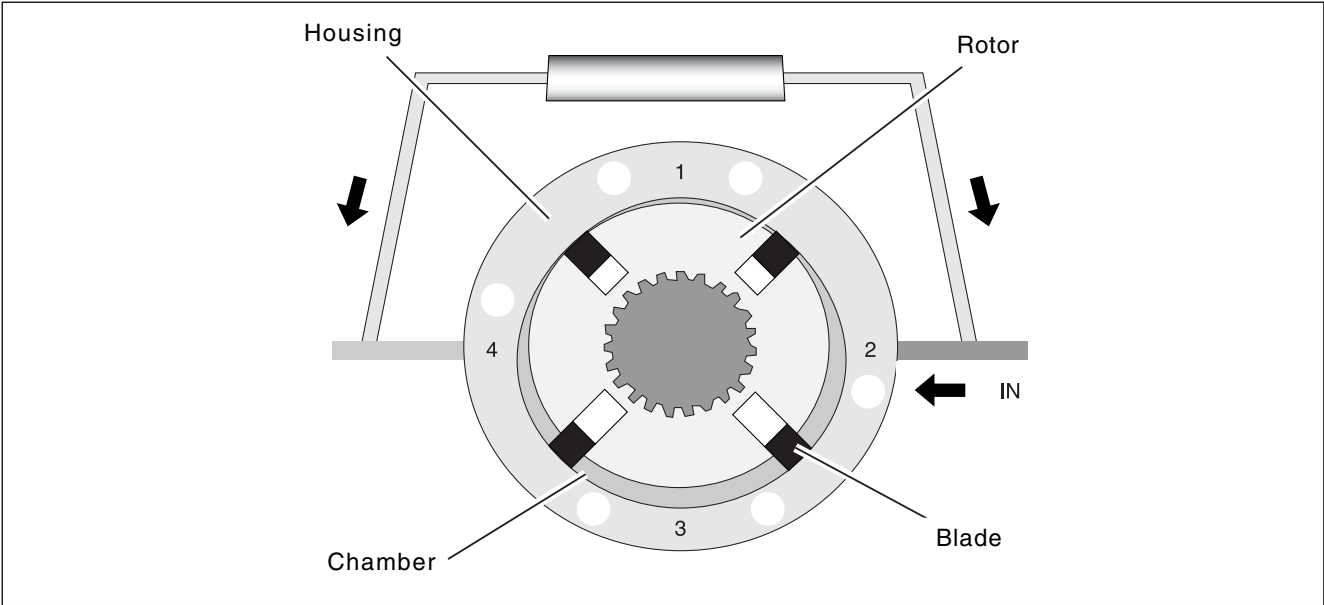
<Sectional Diagram of Fuel Pump>



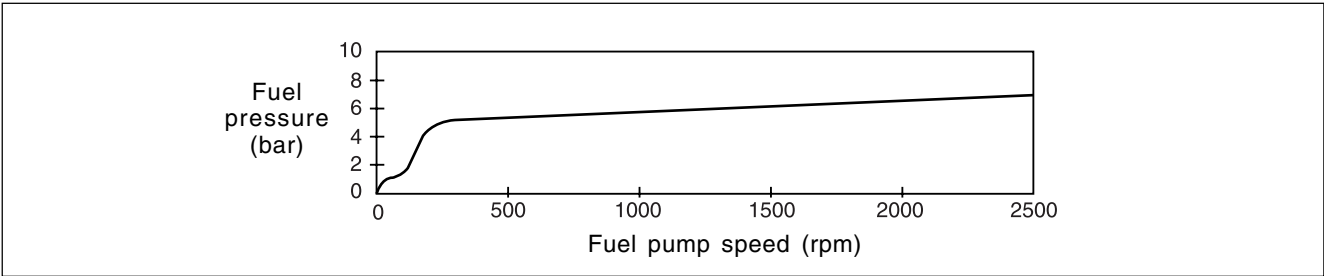
<Sectional Diagram of Transfer Pump>

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Principle of operation



- Consider the chamber between the rotor, the liner and two successive blades (refer to above figure).
1. When the chamber is in position 1, the volume of the chamber is minimal. The changes in volume according to the angle of rotation of the rotor are small.
 2. The rotor makes a quarter turn clockwise. The previous chamber is now in position 2.
The inlet orifice is uncovered. The volume contained in the chamber quickly rises. The pressure inside the chamber drops sharply. Fuel is drawn into the chamber.
 3. The rotor continues to rotate. It is now in position 3. The inlet and outlet orifices are now sealed off. The volume area controlled by the rotor, the liner and the two blades is at the maximum. The changes in volume according to the angle of rotation of the rotor are small.
 4. The rotor continues to rotate. It is finally in position 4. The outlet orifice is uncovered. The volume area controlled by the rotor, the liner and the blades decreases quickly. The pressure inside the chamber rises sharply. The fuel is expelled under pressure. The depression caused by the transfer pump's rotation is sufficient to draw in diesel fuel through the filter. The transfer pump is driven by the shaft of the HP pump, transfer pressure thus rises with engine speed. A regulating valve allows the transfer pressure to be maintained at a practically constant level (about 6 bar) throughout the whole range of engine operations by returning some of the fuel to the pump inlet.



Characteristics of the transfer pump

Regulating pressure	6 bar
Volume controlled	5.6 cm ³ /revolution
Flow	90 ℓ/h at 300 rpm pump
	650 ℓ/h at 2,500 rpm pump
Intake capacity	65 mbar at 100 rpm pump

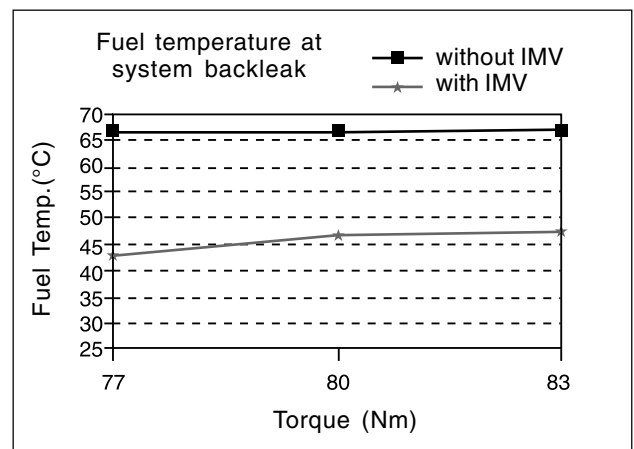
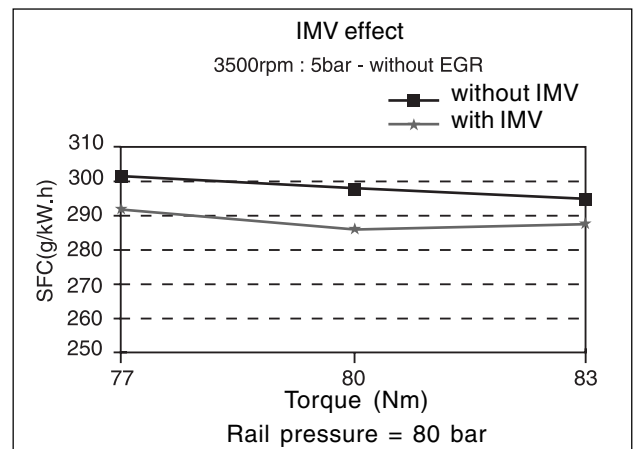
INLET METERING VALVE (IMV)

► Overview

The LP actuator, also called the inlet metering valve, is used to control the rail pressure by regulating the amount of fuel which is sent to the pumping element of the HP pump.

This actuator has two purposes:

1. Firstly, it allows the efficiency of the injection system to be improved, since the HP pump only compresses the amount of fuel necessary to maintain in the rail the level of pressure required by the system as a function of the engine's operating conditions.
2. Secondary, it allows the temperature to be reduced in the fuel tank. When the excess fuel is discharged into the back leak circuit, the pressure reduction in the fluid (from rail pressure down to atmospheric pressure) gives off a large amount of heat. This leads to a temperature rise in the fuel entering the tank. In order to prevent too high a temperature being reached, it is necessary to limit the amount of heat generated by the fuel pressure reduction, by reducing the back leak flow. To reduce the back leak flow, it is sufficient to adapt the flow of the HP pump to the engine's requirements throughout its operating range.



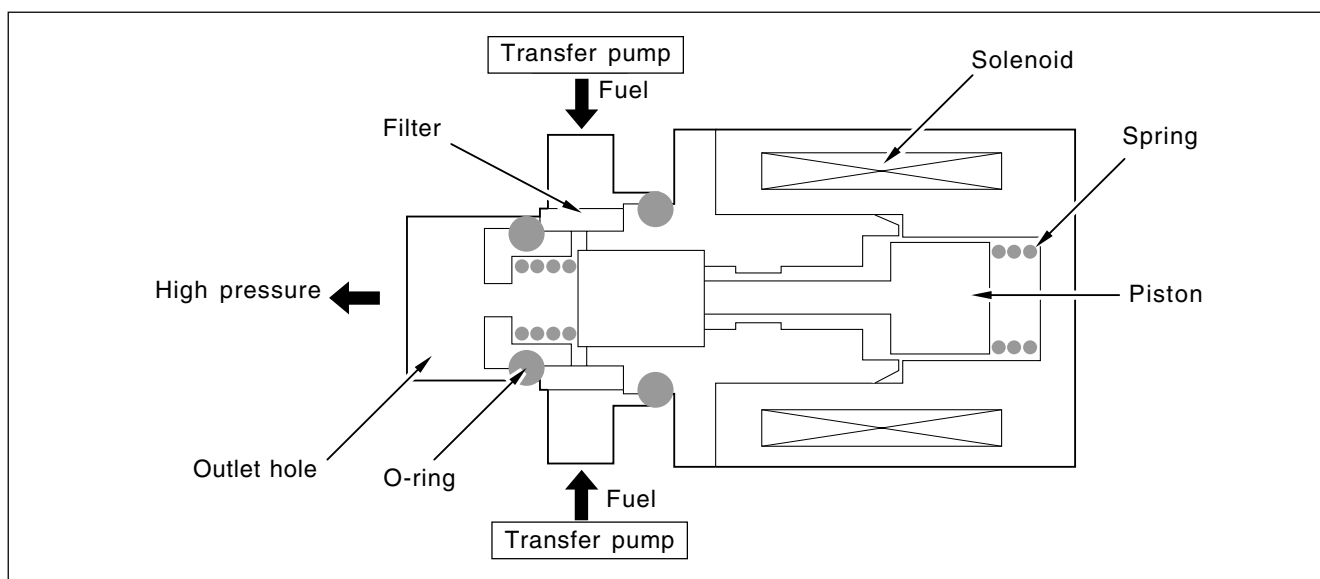
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► Composition of IMV

The IMV is located on the hydraulic head of the pump. It is fed with fuel by the transfer pump via two radial holes. A cylindrical filter is fitted over the feed orifices of the IMV. This makes it possible to protect not only the LP actuator, but also all the components of the injection system located downstream of the IMV.

The IMV consists of the following components:

1. A piston held in the fully open position by a spring.
2. A piston filter located at inlet.
3. Two O-rings ensuring pressure tightness between the hydraulic head and the body of the IMV.
4. A body provided with two radial inlet holes and an axial outlet hole.
5. Coil



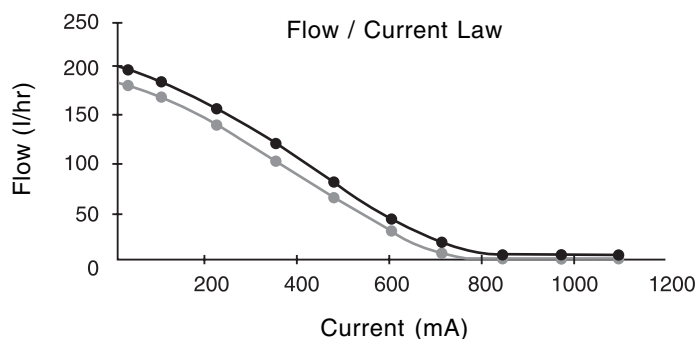
► Principle of Operation

The LP actuator is used to proportion the amount of fuel sent to the pumping element of the HP pump in such a way that the pressure measured by the HP sensor is equal to the pressure demand sent out by the ECU. At each point of operation, it is necessary to have:

- Flow introduced into the HP pump = Injected flow + Injector backleak flow + injector control flow

The IMV is normally open when it is not being supplied with fuel. It cannot therefore be used as a safety device to shut down the engine if required.

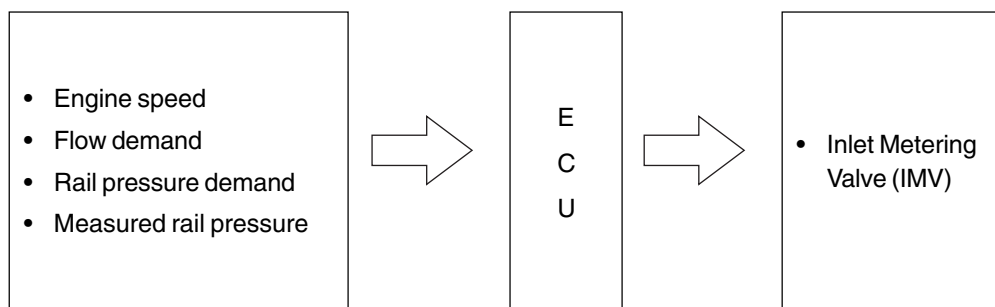
The IMV is controlled by current. The flow/current law is represented below.



Specifications

Piston stroke	1.4 mm
Diameter of holes	3.4 mm
Coil resistance	5.4 Ω (at 25°C)
Power supply	Battery voltage (It is prohibited to supply the IMV directly at the battery voltage during the diagnostic test)
Max. current	1 A
Weight	260 g
Operating temperature	40°C < T < 125°C
Fluid temperature	40°C < T < 90°C
Control logic	Normally open without power (The flow decreases as the current rises).

- ECU determines the value of the current to be sent to the IMV according to:



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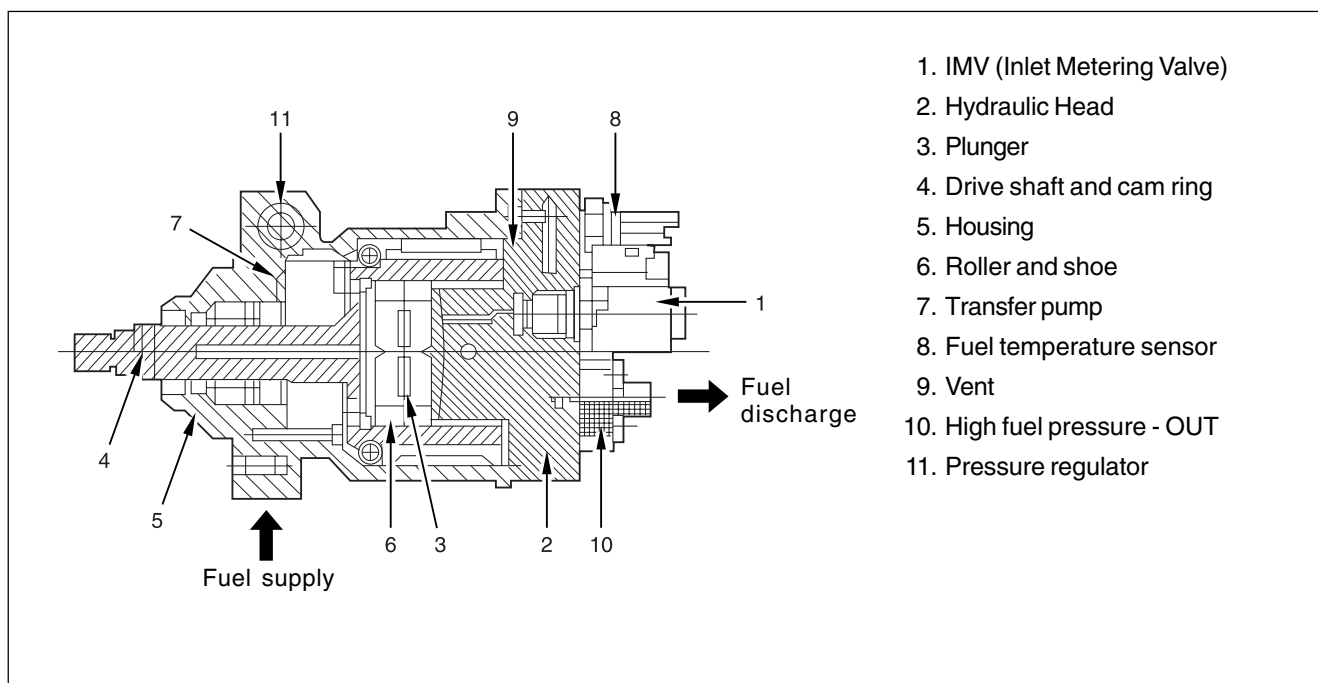
HIGH FUEL PRESSURE LINE

► High Pressure Pump

Description

This pump generates high fuel pressure and is driven by timing chain (radial plunger principle). This pump pressurizes the fuel to approx. 1600 bar and sends this high pressurized fuel to high pressure accumulator (common rail) via high pressure line.

It is possible to extend the pumping phase in order to considerably reduce drive torque, vibration and noise since the pump no longer determines the injection period. The differences from conventional rotary pumps lies in the fact that it is no longer the hydraulic head rotor which turns inside the cam, but the cam which turns around the hydraulic head. Thus, any problems of dynamic pressure tightness are eliminated because the high pressure is generated in the fixed part of the pump.

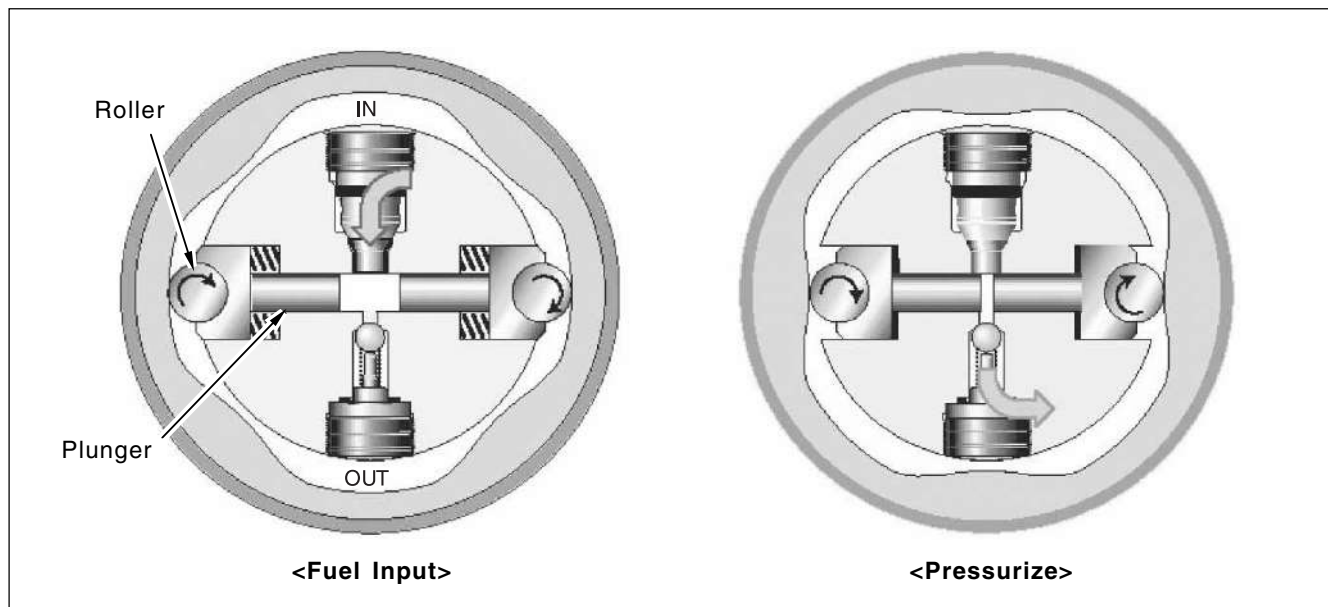


Specifications

1. Maximum operating pressure: 1600 ± 150 bar
2. Operating pressure limit: 2100 bar
3. Maximum sealing pressure: when using a plug instead of PRV, no leaks around pump outlet port (when applying 2500 bar of constant pressure)
4. Fuel pressure at inlet (pressure regulating valve): 6 bar
5. Operating temperature: Continuously operating within temperature range of $-30^{\circ}\text{C} \sim 120^{\circ}\text{C}$ in engine compartment
6. Inflowing fuel temperature: The maximum inflowing fuel temperature is 85°C (continuously able to operate)
7. Pump inlet pressure: Relative pressure Max. 0.48 bar (to end of filter's lifetime)
8. Driving torque: 15 Nm / 1600 bar
9. Gear ratio (engine: pump): 0.625
10. Lubrication: - Inside lubrication (rear bearing): Fuel
 - Outside lubrication (front bearing): Engine oil

Principle of operation

1. During the filling phase, the rollers are kept in contact with the cam by means of coil springs mounted on either side of each shoe. The transfer pressure is sufficient to open the inlet valve and to move the pumping plungers apart. Thus, the dead volume between the two plungers fills with fuel.
2. When the diametrically opposite rollers simultaneously encounter the leading edge of the cam, the plungers are pushed towards each other.
3. As soon as the pressure becomes higher than the transfer pressure, the inlet valve closes. When the pressure becomes higher than the pressure inside the rail, the delivery valve opens. Consequently, the fuel is pumped under pressure into the rail.
4. During the input phase, transfer pressure pushes back the inlet valve. Fuel enters the body of the pumping element. The valve closes as soon as the pressure in the pumping element becomes higher than the transfer pressure.
5. During the input phase, the ball of the delivery valve is subject to the rail pressure on its outer face and to the transfer pressure on its inner face. Thus the ball rests on its seat, ensuring the pressure tightness of the body of the pumping element. When the pressure in the element becomes higher than the pressure in the rail, the ball is unbalanced and it opens. Fuel is then pumped into the rail at high pressure.

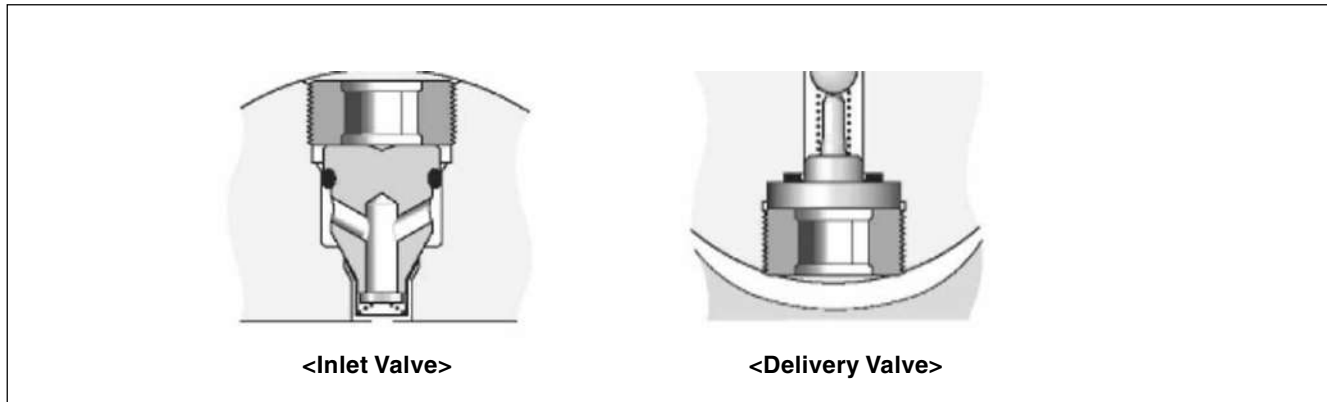


This high pressure pump generates the driving torque with low peak torque to maintain the stress to driving components. This torque is smaller than that of conventional injection pump, thus, only a small load will be applied to pump. The required power to drive pump is determined by set pressure for rail and pump speed (delivery flow). Note that the fuel leakage or defective pressure control valve may affect the engine output.

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Inlet valve and delivery valve

During the input phase, transfer pressure pushes back the inlet valve. Fuel enters the body of the pumping element. Under the effect of the transfer pressure, the two plungers are forced apart. When the rollers simultaneously encounter the leading edge of the cam, pressure suddenly rises in the body of the pumping element. The valve closes as soon as the pressure in the pumping element becomes higher than the transfer pressure. During the input phase, the ball of the delivery valve is subject to the rail pressure on its outer face and to the transfer pressure on its inner face. Thus the ball rests on its seat, ensuring the pressure tightness of the body of the pumping element. When the two diametrically opposite rollers encounter the leading edges of the cam, the plungers are forced together and pressure quickly rises in the body of the pumping element. When the pressure in the element becomes higher than the pressure in the rail, the ball is unbalanced and it opens. The spring calibration is negligible compared with the pressure forces. Fuel is then pumped into the rail at high pressure.



Lubrication and cooling of the HP pump

Lubrication and cooling of the pump are provided by the fuel circulation. The minimum flow required to ensure adequate operation of the pump is 50 l/h.

Phasing of the HP pump

Conventional fuel injection pumps ensure pressurizing and distribution of the fuel to the different injectors. It is essential to set the pump in such a way that the injection occurs at the required place during the cycle. The HP pump of the common rail system is no longer used for the fuel distribution, it is therefore not necessary to set the pump in relation to the engine.

Nevertheless, the setting or phasing of the pump offers two advantages:

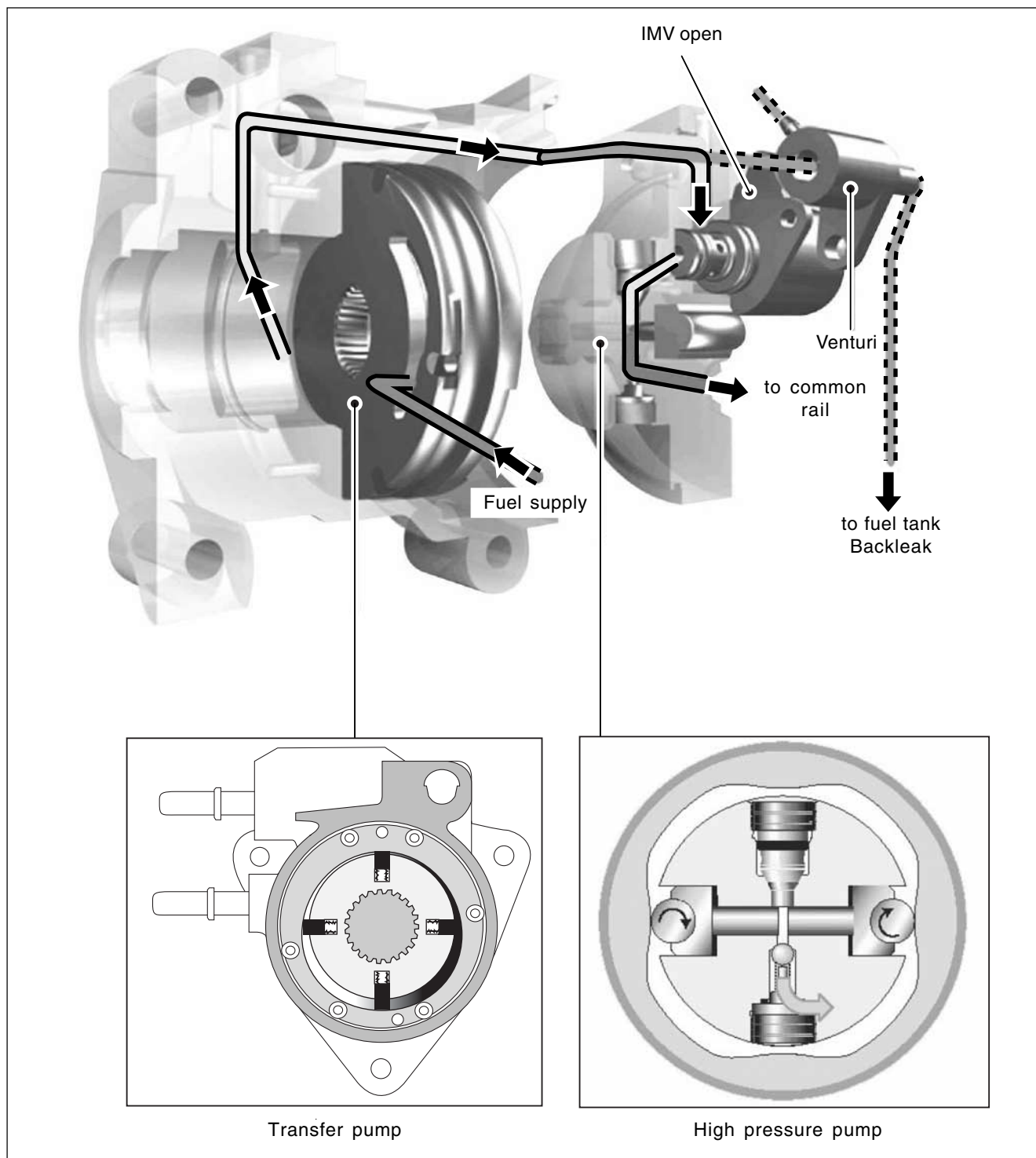
1. It allows the torque variations of the camshaft and the pump to be synchronized in order to reduce the stresses on the timing belt.
2. It allows pressure control to be improved by synchronizing peak pressures produced by the pump with pressure-drops caused by each injection.

This phasing allows pressure stability to be improved, which helps to reduce the difference in flow between the cylinders.

► HP Pump Fuel Route

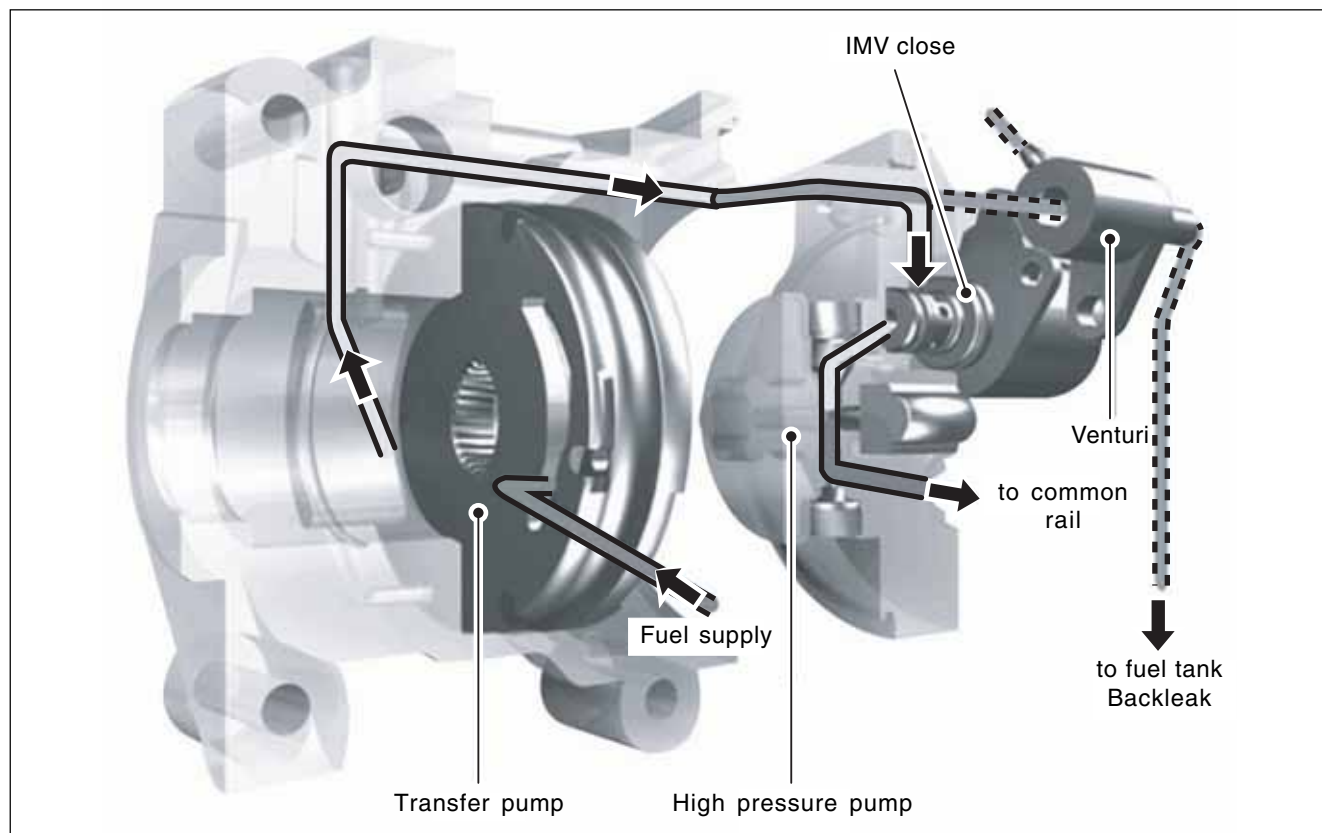
The fuel passed through the fuel filter is sent to the transfer pump via the HP inlet pump. this fuel passes through the transfer pump by the transferring pressure and maintains the predefined value by the regulating valve in HP pump. Also, this fuel gets into the IMV that controls only the fuel to the high pressure pump. The below figure describes the pump operations when acceleration and deceleration.

When need high fuel pressure (acceleration)



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When do not need high fuel pressure (deceleration)



The fuel is sent to the high pressure side (hydraulic head) and compressed by the plunger. And, goes into the common rail through the high pressure pipe.

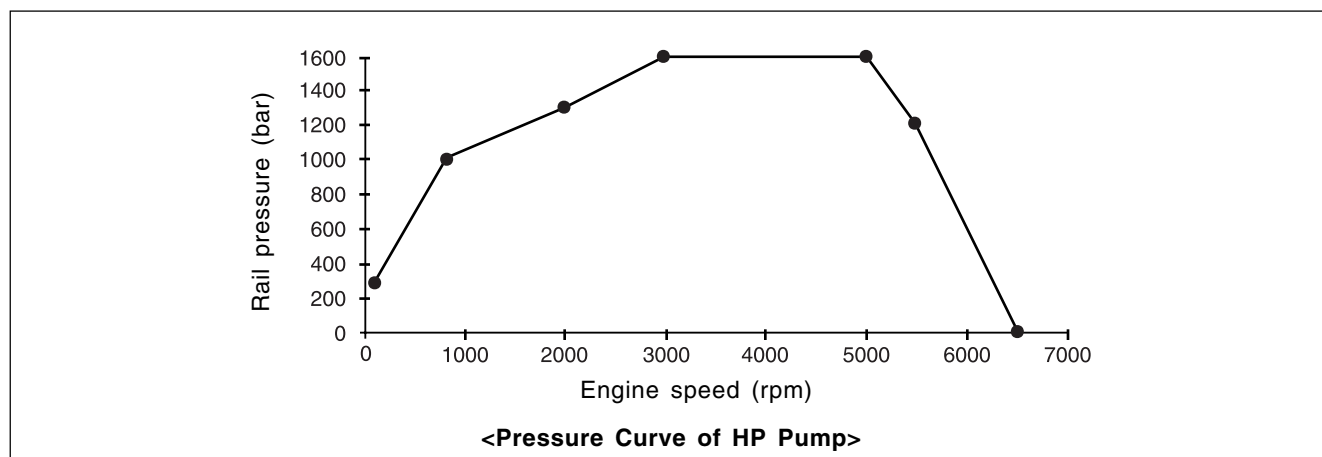
The IMV installed in the high pressure side (hydraulic head) of HP pump precisely controls the fuel amount and delivers the rail pressure feedback same as required amount.

The IMV is controlled by ECU.

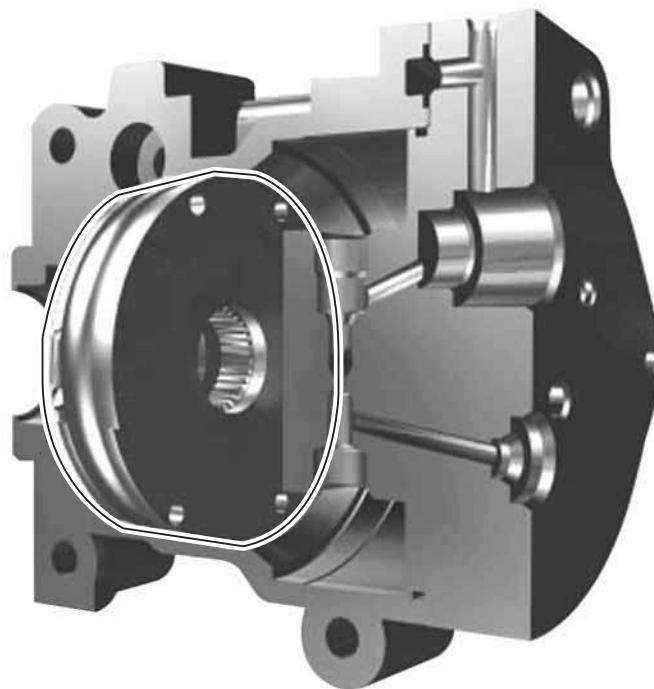
Performance curve of HP pump

The time required to obtain a sufficient pressure in the rail to enable the engine to start depends on the volume of the system (definition of the rail, length of the pipes, etc.). The aim is to reach a pressure of 200 bars in 1.5 revolutions (3rd compression).

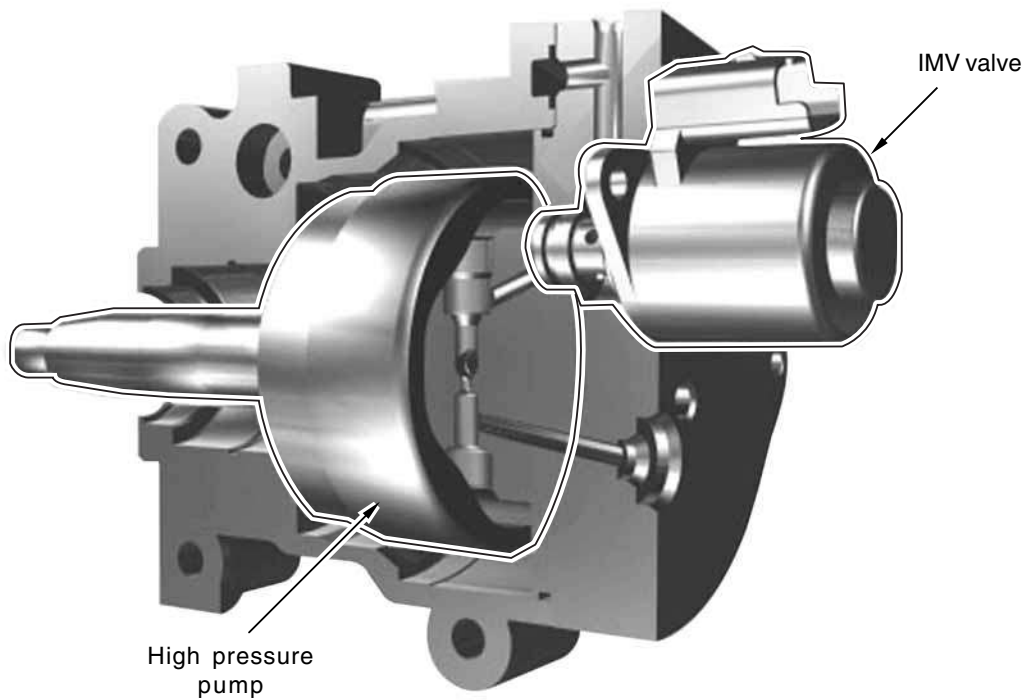
- Maximum operating pressure: 1600 ± 150 bar



► Sectional View of HP Pump

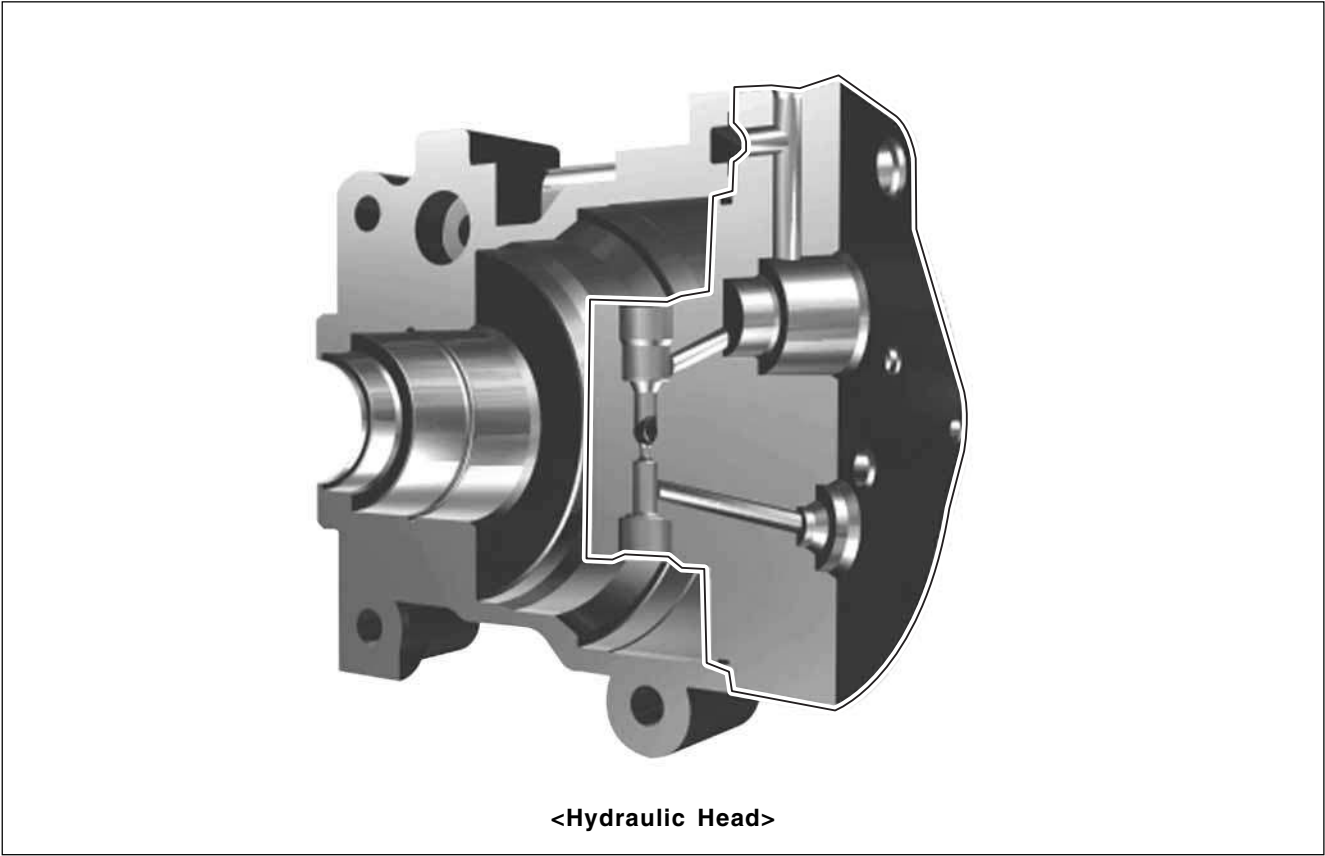
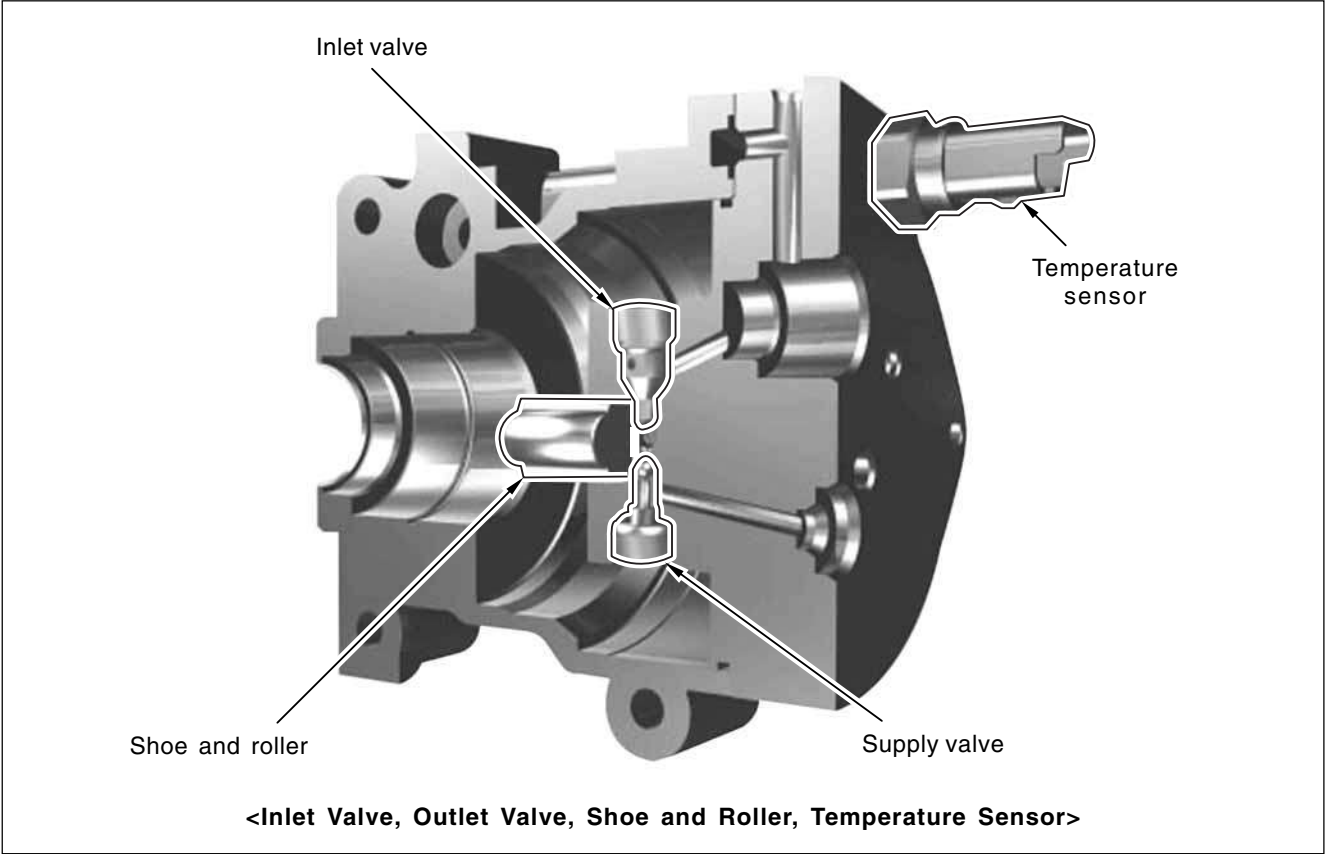


<Transfer Pump>



<IMV Valve and High Pressure Pump (Drive Shaft)>

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► Removal and Installation

Removal

※ Preceding Works:

1. Disconnect the negative battery cable.
2. Apply the parking brake and place the chocks under the tires. (transmission "N" position)

1. Turn the auto tensioner counterclockwise and remove the fan belt.



NOTICE

- Slacken the pulley bolt.



2. Remove the engine belt pulleys.

- 1) Cooling fan pulley
- 2) Coolant pump pulley
- 3) Idle pulley



3. Unscrew lower bolt (13 mm) and upper bolt (24 mm) and remove the auto tensioner.



NOTICE

- To prevent oil leaks, store the removed auto tensioner in upright position.
- Pump the auto tensioner several times before installing it.



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6. Remove the high pressure pump housing.

※ **Preceding Work:** Remove the No.2 EGR pipe.



7. Align the OT mark by rotating the crankshaft.

- 1) Open the oil filler cap and check if the OT mark on crankshaft is aligned to the notch on the camshaft.



8. Unscrew the bolts and remove the vacuum modulator bracket.

- 1) Disconnect the high pressure pump and vacuum modulator connector.
- 2) Disconnect the fuel lines to high pressure pump.
- 3) Plug the openings of pipes and ports with protective caps to keep the cleanness of the fuel system.
- 4) Remove the high pressure fuel pipe between HP pump and common rail.



9. Rotate the crankshaft clockwise so that the HP pump sprocket holes are aligned to the bolt holes.



8. Hold the HP pump sprocket and slacken the center bolt.



9. Slacken three HP pump mounting bolts until they rest on the sprocket.



10. Loose the HP pump center nut by tapping it with a hammer.

**NOTICE**

- Tap the center bolt with a hammer after tightening.
- Make sure that the center bolt is securely tightened.



11. Remove the remaining bolts with the same manner and remove the high pressure pump.



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Installation

1. Replace the HP pump gasket with new one (cannot be reused).



2. Tighten the HP pump bolts.

Tightening torque	25 Nm
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3. Hold the HP pump sprocket and tighten the center nut.

Tightening torque	65 Nm
-------------------	-------

NOTICE

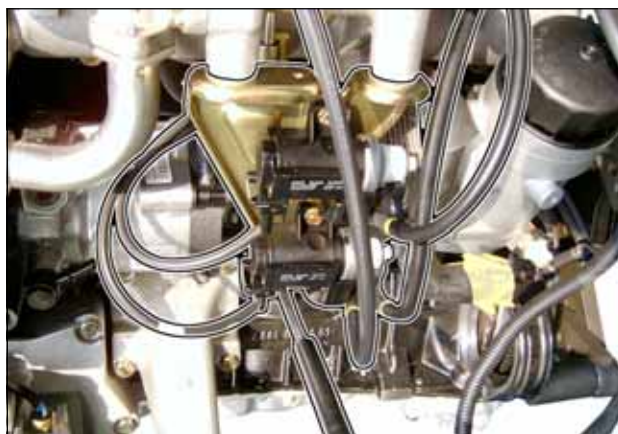
- The center nut should be replaced once removed (cannot be reused).
- Tighten the center nut with the specified tightening torque.



4. Install the vacuum modulator bracket.

NOTICE

- Replace the fuel lines to HP pump with new ones (cannot be reused).
- Make sure that the connectors are installed to the correct locations. (The wiring end with white tape)



5. Apply the sealant to the HP pump housing and tighten the bolts.

**NOTICE**

- Sealant (DB2210): 661 989 56 A0



6. Install the auto tensioner and belt pulleys.



7. Rotate the crankshaft pulley two revolutions and ensure that the OT mark on the crankshaft pulley and the OT mark on the camshaft pulley are aligned.

**NOTICE**

- Open the oil filler cap and check if the OT mark on crankshaft is aligned to the notch on the camshaft.



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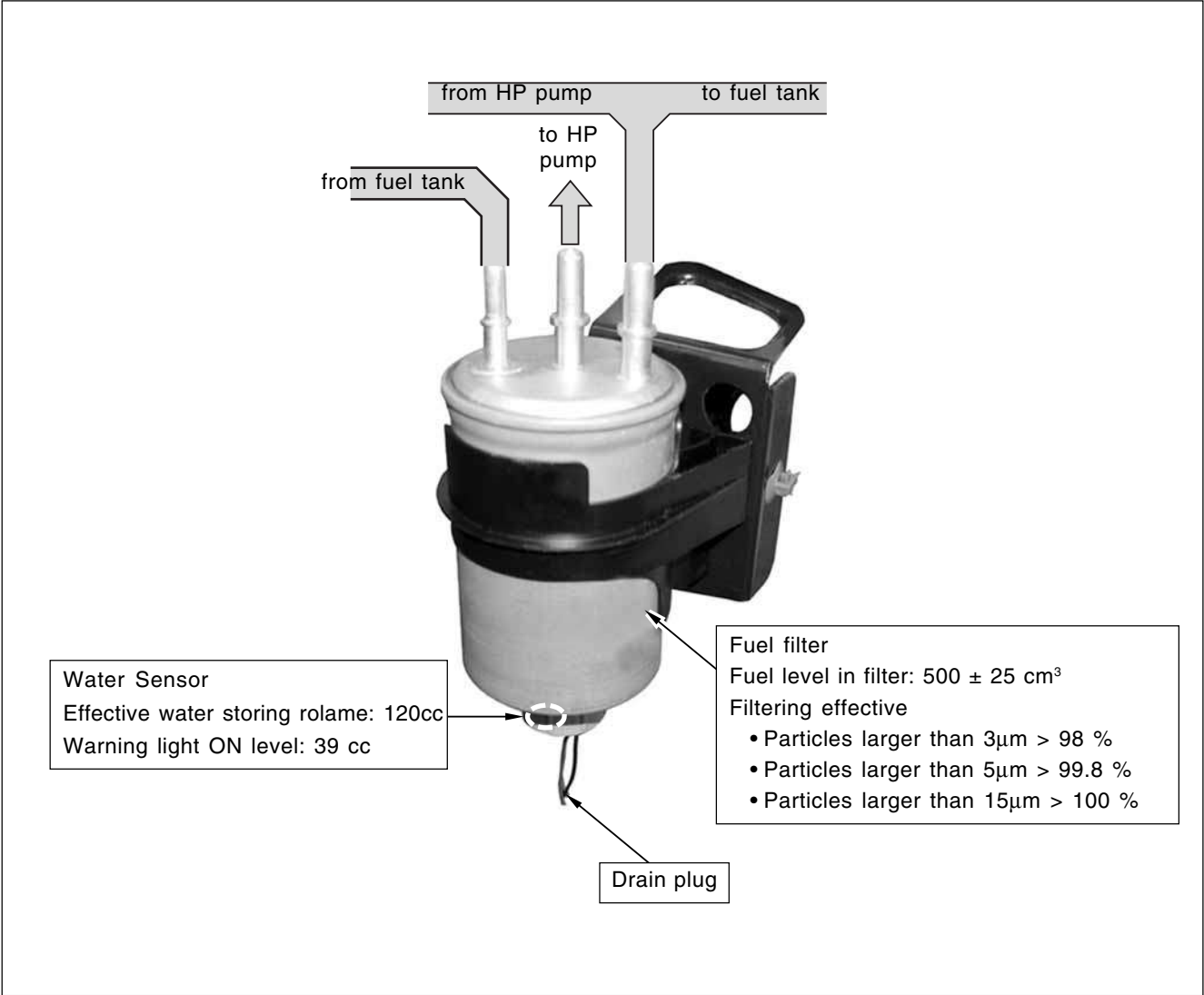
SENSOR

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► Fuel Filter

Function

Foreign materials in fuel can damage the pump components, transfer valve and injectors. Therefore, the high pressure direct injection engine must use fuel filter. Otherwise, the operation performance will drop dramatically. And, diesel fuel may contain water due to condensation by temperature changes and this condensation water can damage the system by corroding the injection system. Thus, the common rail engine should have function that can drain water periodically.



Change Interval: 30,000 km

Water separation and storage function

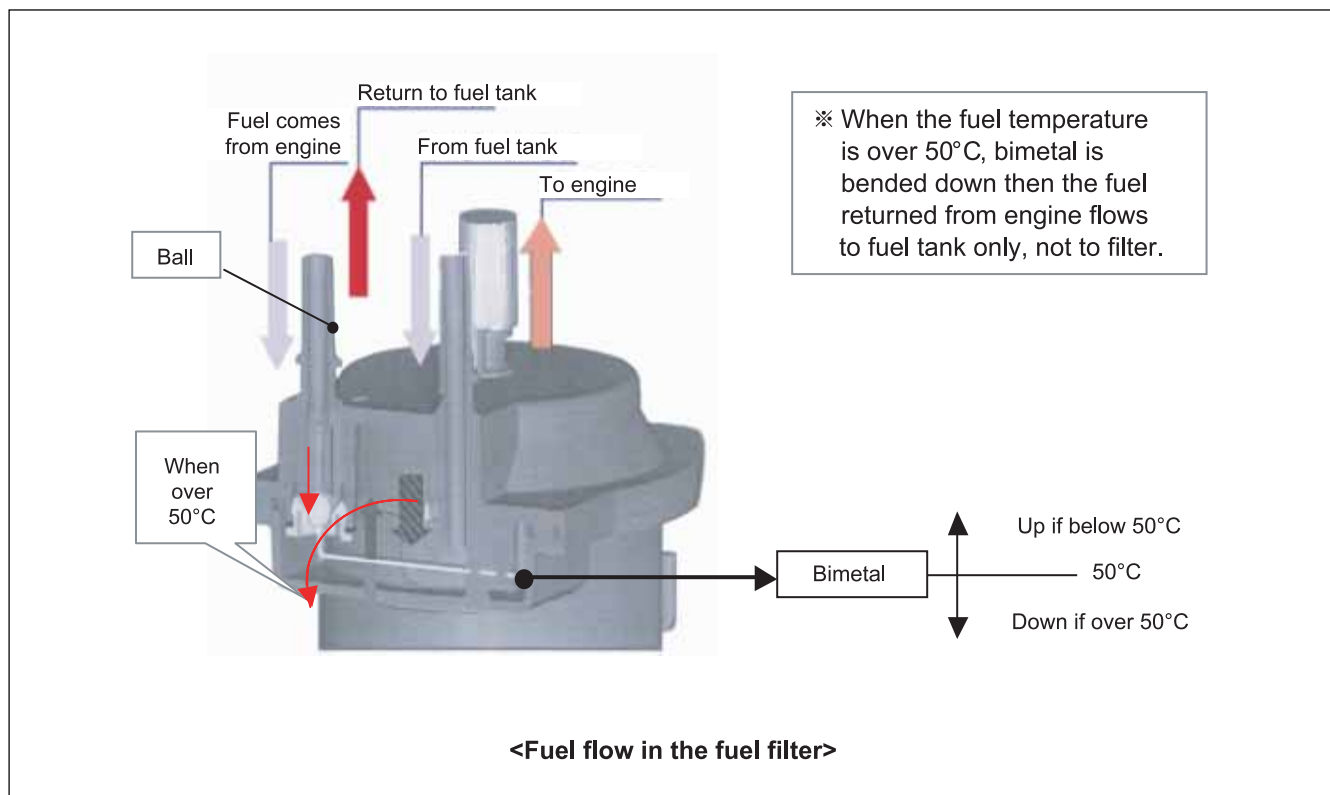
1. Function: It separates the condensation water from diesel fuel to prevent the water from getting into FIE system, and results in protection of FIE system. (manual drain)
2. Water reserve capacity: 124 cc
3. Water warning light turning on level: 39 cc
4. Water drain interval: When changing engine oil or every 20,000 km

Water sensor

It is integrated in the filter and sends signal to ECU when water level reaches at a specified value (over 75 cc) in the filter to let the driver drain the water.

Fuel De-Waxing – Improving starting performance in cold weather

Due to characteristics of diesel fuel, some of fuel components solidify during cold winter under below a specific temperature (-15°C). When those symptoms happen, engine may stall; however, some of the fuel (temperature rises due to high compression) in the HP pump in D27DT engine return to the filter to warm up fuel when temperature is below 50°C by improving cold start performance during cold winter.



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Removal and Installation

1. Disconnect the fuel supply and return hoses.



NOTICE

- Plug the openings of hoses and fuel filter with sealing caps.
- Ensure that the hoses are connected to correct positions.

2. Loosen the bracket bolts and disconnect the hose from the drain plug.
3. Remove the fuel filter.
4. Install in the reverse order of removal.
5. Press the priming pump until it becomes rigid to deliver the fuel to the transfer line of HP pump.



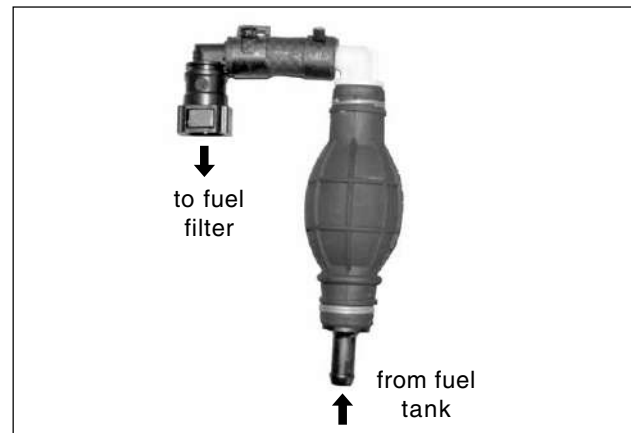
► Priming Pump

If fuel runs out during driving or air gets into fuel line after fuel filter replacement, it may cause poor engine starting or damage to each component. Therefore, the hand priming pump is installed to bleed air from transfer line.

When the vehicle is under the conditions as below, press the priming pump until it becomes rigid before starting the engine.

Conditions for using Priming Pump

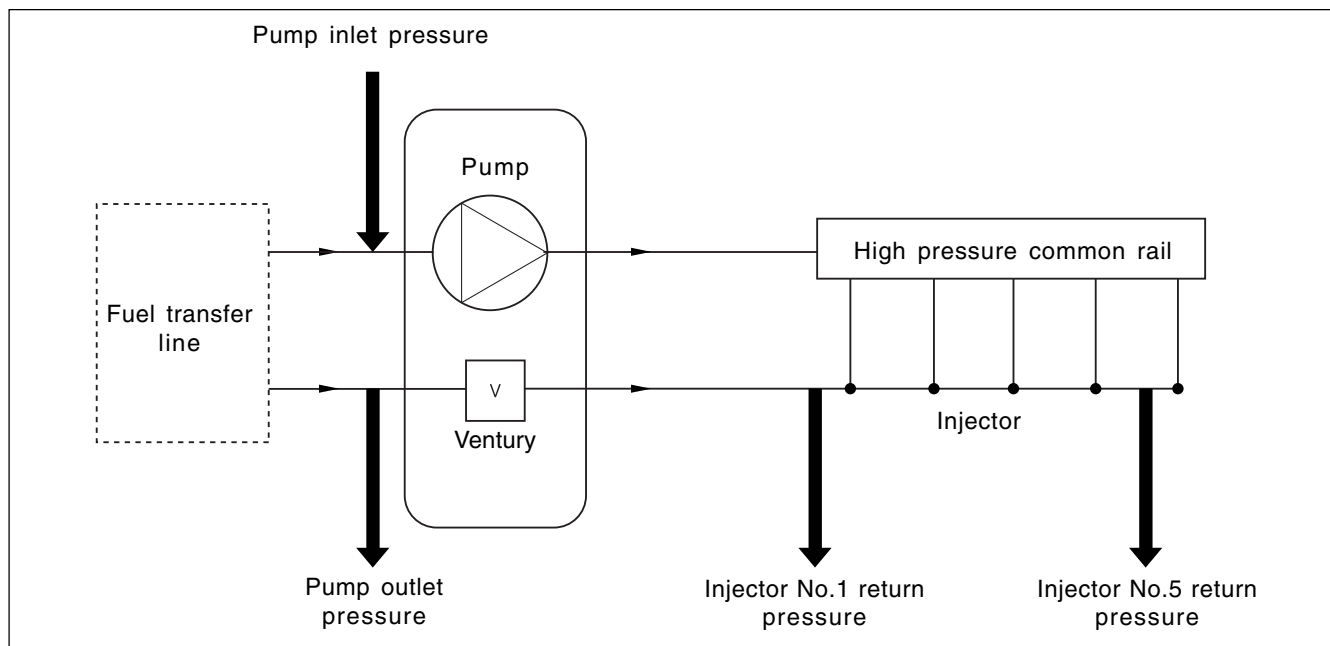
1. After run out of fuel
2. After draining the water from fuel separator
3. After replacing the fuel filter



NOTICE

- When the fuel filter is replaced, the fuel in the fuel tank should be transferred to the filter by using priming pump. So never transfer the fuel in the fuel tank to the filter by driving HP pump with cranking the engine.

► Relations Between Pressure and Temperature in Fuel Transfer Line



1. The fuel transfer line is the line between fuel tank and HP pump inlet port. The pressure on this line affects the lifetime of fuel filter.
2. Temperature of fuel transfer line
 - 1) Pump inlet temperature is less than 80°C.
 - 2) Above figure shows the temperature changes in each section caused by temperature changes in pump inlet section; the temperature of fuel pump inlet is up to 80°C.
And, diesel fuel has lubrication effects due to its viscosity. Thus, the fuel is also used for pump lubrication. However, this lubrication performance drops as the temperature rises. Accordingly, when the fuel temperature is over 50°C, 100% of fuel is returned to fuel tank to cool down the temperature and then increase the lubrication effects of fuel and prevent heat damage on each section of high fuel pressure line.

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► High Pressure Accumulator (Common Rail)



Description

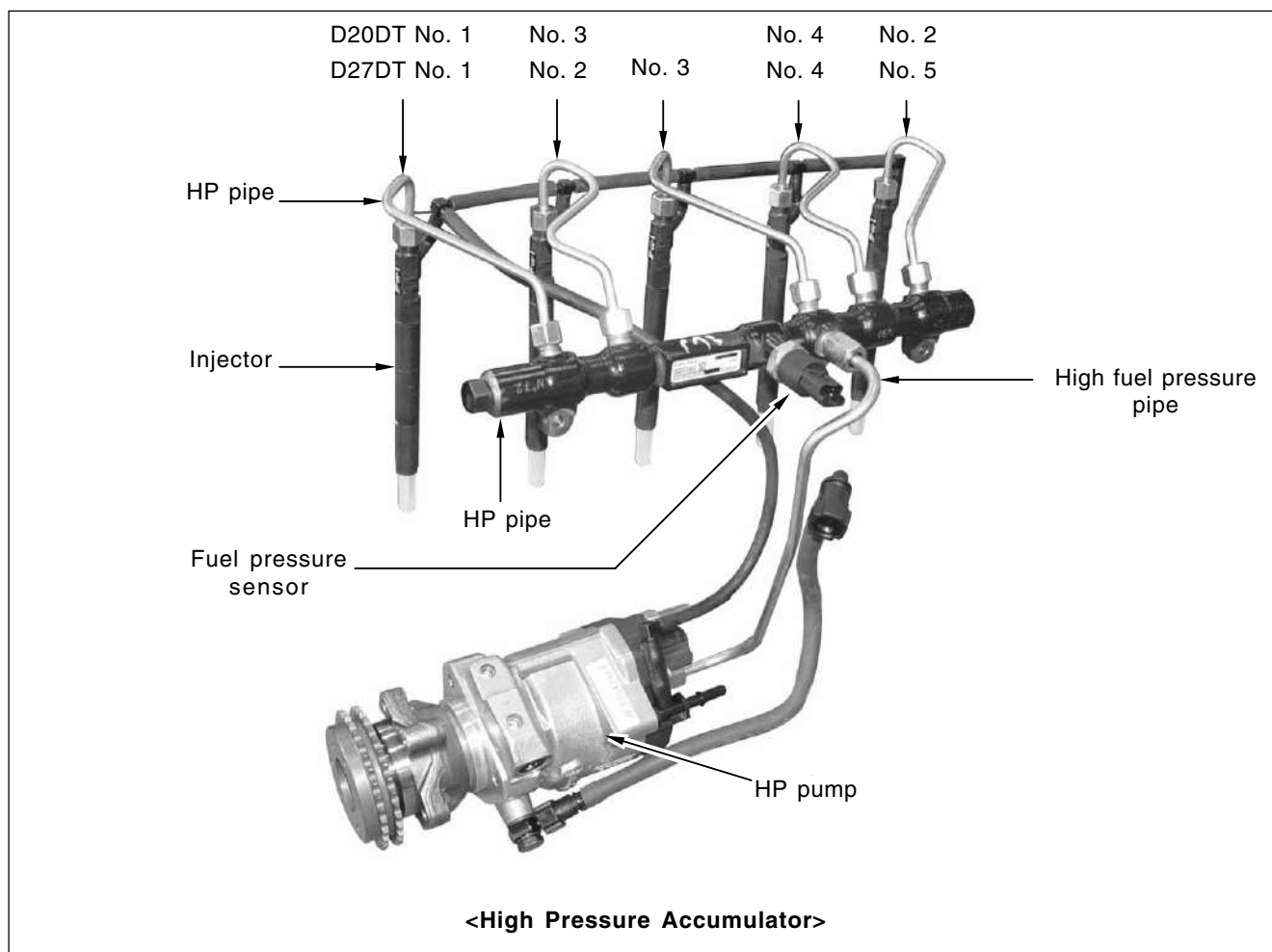
The high pressure accumulator reserves the high pressure fuel. Simultaneously, the pressure changes due to the delivery from HP pump and the fuel injection is diminished by rail volume. This high pressure accumulator is commonly used in all cylinders. Even when a large amount of fuel leaks, the common rail maintains its internal pressure. This ensures that the injection pressure can be maintained from when the injector opens.

Function

1. Relieve the pressure pulsation
2. Provide pressure information to ECU (fuel pressure sensor)

Specifications

1. Material: Forged Steel
2. Dimension:
 - Volume: $19.5 \pm 1\text{cc}$
 - Length: Max. 345.11 mm
 - Outer diameter: 27 mm
3. Fuel pressure sensor Integrated type
 - 1) Sensor input voltage: $5 \pm 0.1\text{V}$
 - 2) Sensor output signal voltage:
 - $4.055 \pm 0.125\text{ V} \cong 1600 \pm 15\text{ bar}$
 - $0.5 \pm 0.04\text{ V} \cong 0\text{ bar}$
4. Operating pressure range
 - 1) Normal condition: 0 ~ 1800 bar
 - 2) Exceptional condition: available within 1800 ~ 2100 bar
 - 3) Bursting pressure: over 2500 bar
5. Ambient temperature:
 - 1) available within $-40^{\circ}\text{C} \sim 125^{\circ}\text{C}$
 - 2) Spontaneous max. temperature after engine stops: 140°C (acceptable against total 15 hours)
6. Fluid temperature: $-40 \sim 100^{\circ}\text{C}$ under normal operating conditions
7. Removal and installation: 10 times without any damage



► High Fuel Pressure Pipe

1. Function: Resistant to pressure changes, tightness against surroundings, supplying fuel through pump, rail and injector with high pressure
2. Material: Steel (Zn Plated)
3. Common: Cylinder 1, 2, 3, 4
4. Internal pressure
 - 1) Internal operating pressure: 0 ~ 1600 bar during its lifetime
 - 2) Spontaneous max. pressure when restoring: 2100 bar (max. total period: 20 hours)
 - 3) Bursting pressure: over 2500 bar
5. To keep cleanness and tightness, the high pressure pipe assembly should be used only once.



NOTICE

- Make sure to replace the removed high fuel pressure pipes.
- Tighten the fasteners with the specified tightening torque.

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AFFECTED VIN	

Removal and Installation

※ **Preceding Work:** Removal of engine cover

1. Disconnect the fuel pressure sensor connector.



NOTICE

- Replace the fuel pipes with new ones.
- Plug the openings of hole in the common rail with sealing caps.



2. Unscrew the nuts and remove the fuel supply main pipe from the fuel line.

Installation Notice

Tightening torque	$40 \pm 1.0 \text{ Nm}$
-------------------	-------------------------



NOTICE

- Replace the fuel pipes with new ones.
- Plug the openings of hole in the common rail with sealing caps.

3. Unscrew the high fuel pressure line nuts and remove the fuel pipes.

Installation Notice

Tightening torque	$40 \pm 1.0 \text{ Nm}$
-------------------	-------------------------



NOTICE

- Replace the fuel pipes with new ones.
- Plug the openings of hole in the common rail with sealing caps.

4. Unscrew the bolts and remove the common rail assembly.

Installation Notice

Tightening torque	$25 \pm 2.5 \text{ Nm}$
-------------------	-------------------------



NOTICE

- Replace the fuel pipes with new ones.
- Plug the openings of hole in the common rail with sealing caps.



5. Install in the reverse order of removal.

► Fuel Pressure Sensor



Fuel pressure sensor on the center of common rail detects instant fuel pressure changes and then sends to ECU. When received these signals, ECU uses them to control fuel volume and injection time.

The fuel in the rail reaches to sensor diaphragm via blind hole in the pressure sensor and the pressure signal converts to electrical signal. The signal measured by sensor will be amplified to input to ECU.

This piezo element type sensor changes pressure into electrical signal. Accordingly, when the shape of diaphragm changes, electrical resistance in the layers on the diaphragm changes then can measure 0.5 ~ 5 V.

1. Sensor input voltage: 5 ± 0.1 V
2. Output signal voltage of sensor
 - 1) 4.055 ± 0.125 V: 1600 ± 15 bar
 - 2) 0.5 ± 0.04 V: 0 bar

GENERAL

ASSY

HOUSING

INTAKE

EXHAUST

LUB

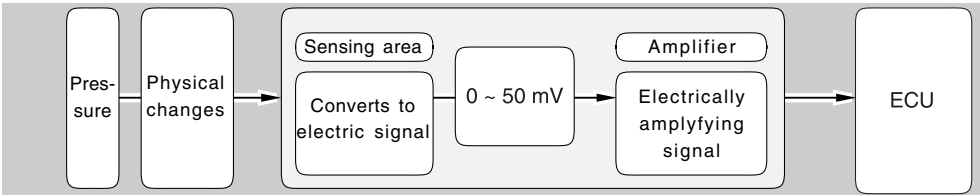
COOLING

FUEL

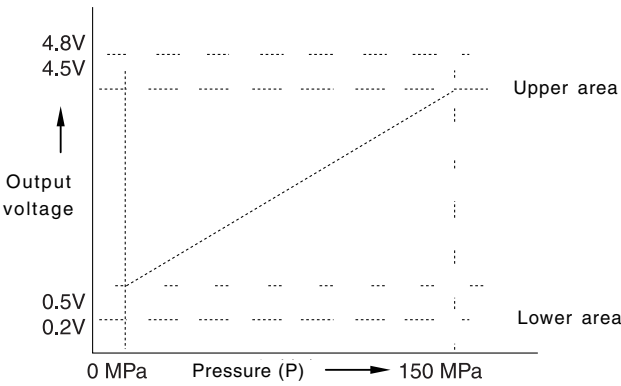
CONTROL

SENSOR

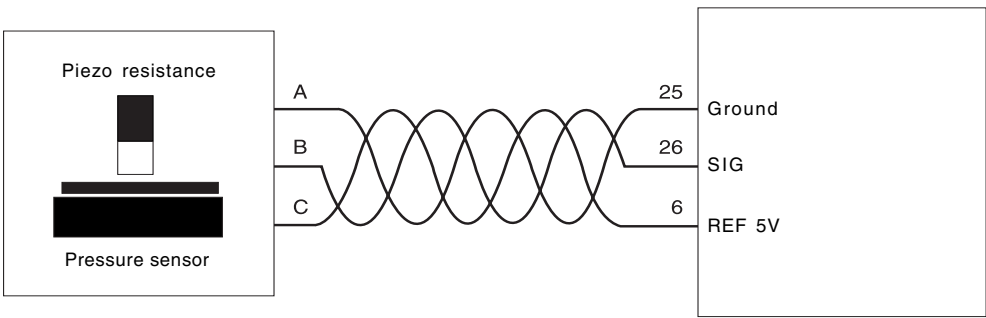
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<Operation Principle of Fuel Pressure Sensor>

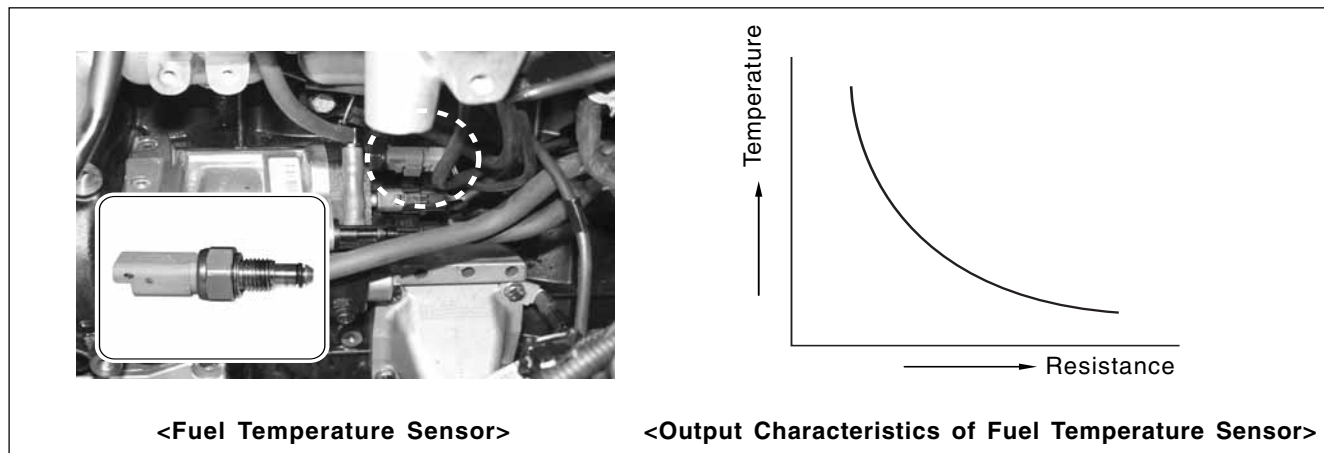


<Sensor Voltage>



<Circuit Diagram of Fuel Pressuer Sensor>

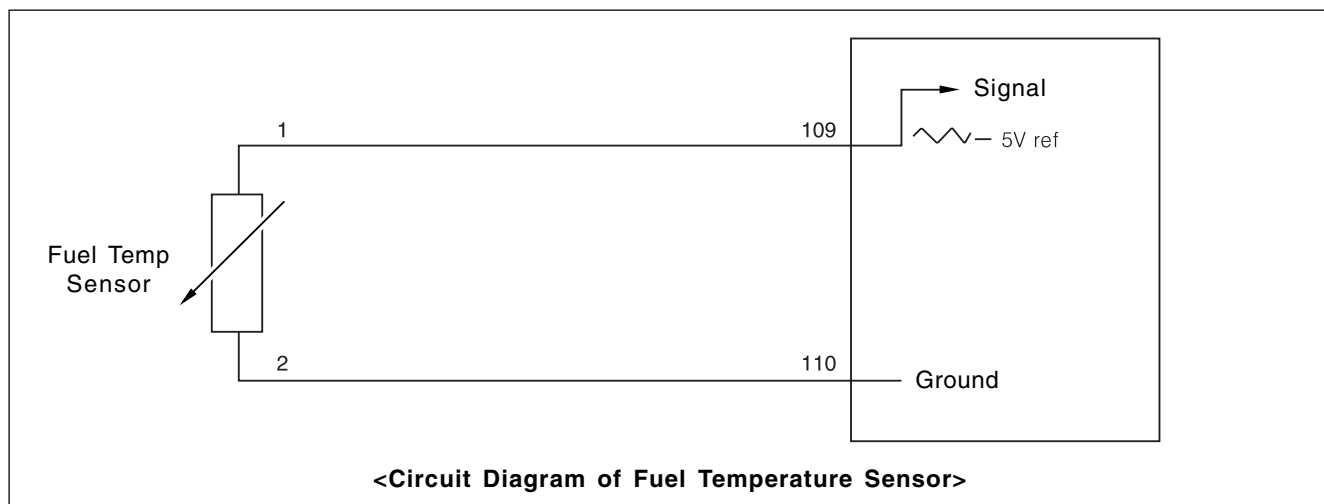
► Fuel Temperature Sensor



Fuel temperature sensor is a NTC resistor that sends fuel temperature to ECU.

In case of NTC resistor, the resistance lowers if engine temperature rises so the ECU detects lowering signal voltages.

Fuel temperature sensor is installed on the fuel return line to correct pressure after measuring fuel temperature. 5V is supplied to the sensor and voltage drop by temperature is delivered to ECU to measure the fuel temperature through analog-digital converter (ADC).



► HFM Sensor

Refer to "Intake System"

► Crankshaft Position Sensor

Refer to "Engine Assembly"

► Knock Sensor

Refer to "Engine Assembly"

► Camshaft Position Sensor

Refer to "Engine Assembly"

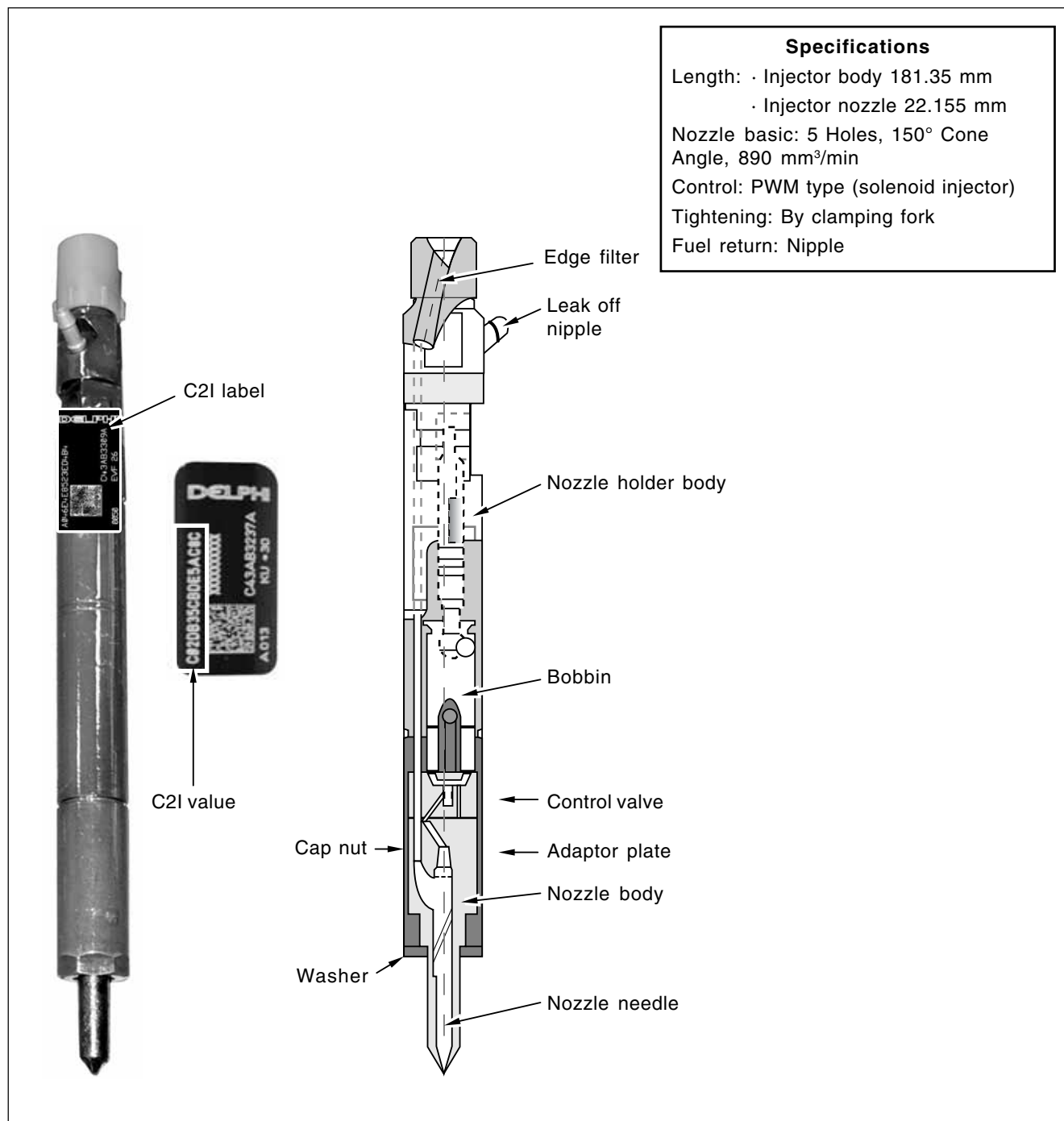
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AFFECTED VIN	

INJECTOR

The C21 labels including injector characteristics are attached in each injector. These C21 values should be input to ECU by using Scan-i when replacing the ECU or injectors.

Special cautions:

1. Plug the openings of hoses and pipes with the sealing caps.
2. Replace the copper washer in injector with new one.
3. Tighten the injector holder bolts with the specified tightening torque.
4. Be careful not to drop the injector.



The maximum injection pressures are approximately 1,600 bar. The forces to be overcome in order to lift the needle of the injector are therefore very large. Because of this, it is impossible to directly control the injector by using an electromagnetic actuator, unless very high currents are used, which would be incompatible with the reaction times required for the multiple injections. The injector is therefore indirectly controlled by means of a valve controlling the pressurizing or discharging of the control chamber located above the needle:

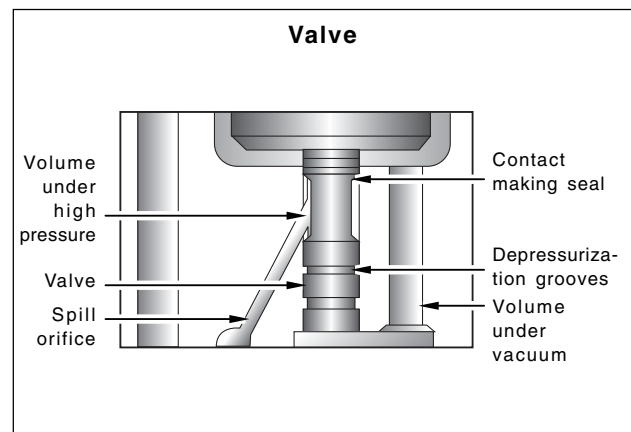
1. When the needle is required to lift (at the start of injection): the valve is opened in order to discharge the control chamber into the back leak circuit.
2. When the needle has to close (at the end of injection): the valve closes again so that pressure is re-established in the control chamber.

Valve

In order to guarantee response time and minimum energy consumption:

1. The valve must be as light as possible.
2. The valve stroke must be as short as possible.
3. The effort needed to move the valve must be minimal, which means that the valve must be in hydraulic equilibrium in the closed position.

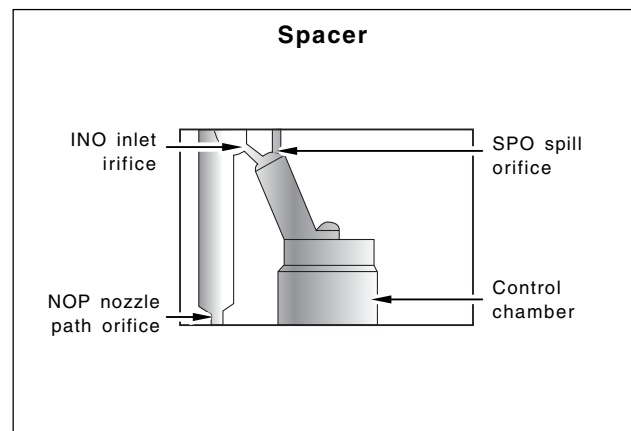
Spring pressure ensures contact between the valve and its seat. To lift the valve, it is therefore required to overcome the force being applied by this spring.



Spacer

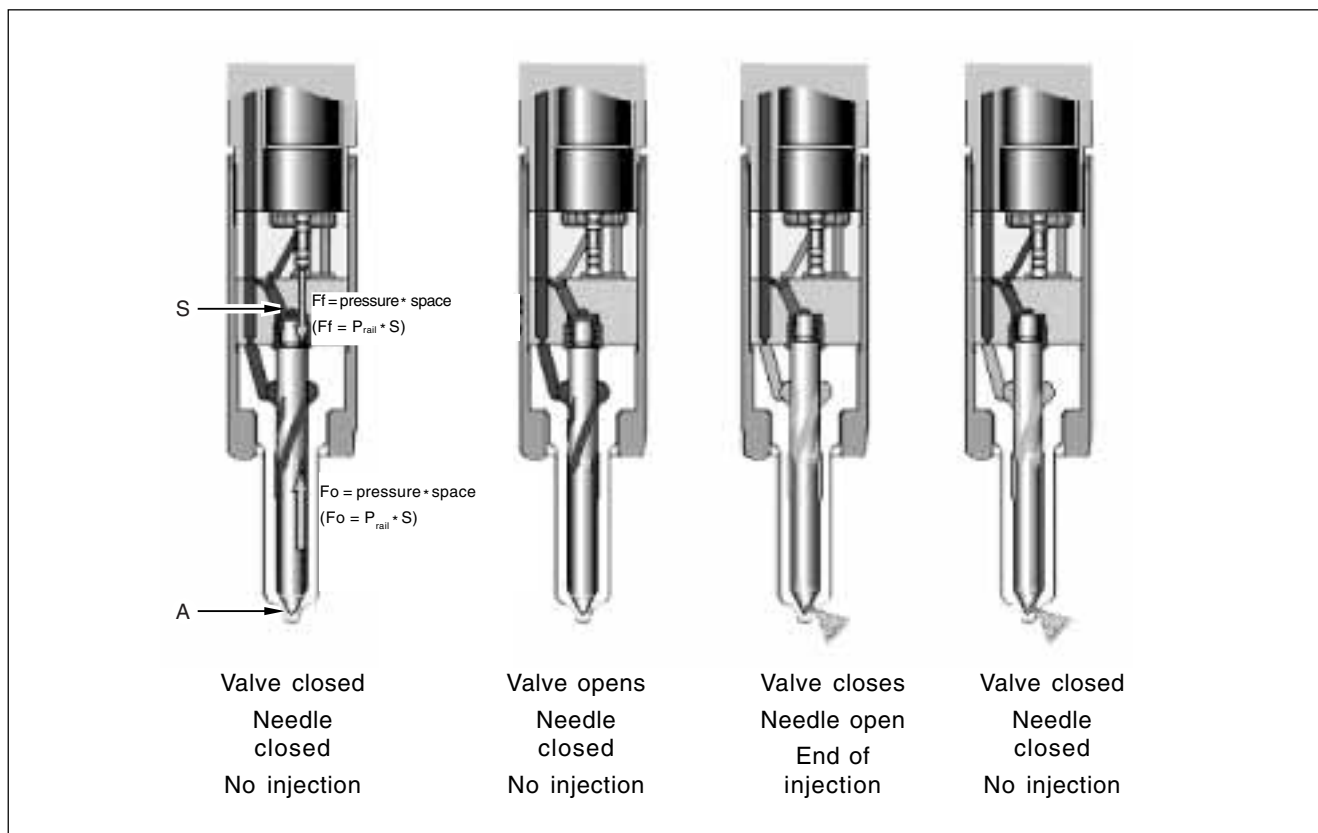
The spacer is situated underneath the valve support. It integrates the control chamber and the three calibrated orifice which allow operation of the injector. These orifices are:

1. The injector supply orifice (Nozzle Path Orifice: NPO)
2. The control chamber discharge orifice (Spill Orifice: SPO)
3. The control chamber filling orifice (Inlet Orifice: INO)



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AFFECTED VIN	

► Principle of Operation



Injector at rest

The valve is closed. The control chamber is subject to the rail pressure.

The pressure force applied by the fuel onto the needle is:

$$F_f = S \times P_{\text{rail}}$$

The needle is closed and hence there is no fluid circulation through the NPO orifice. While static, the nozzle produces no pressure drop. The cone of the needle is therefore subject to the rail pressure. The force applied by the fuel to the needle is:

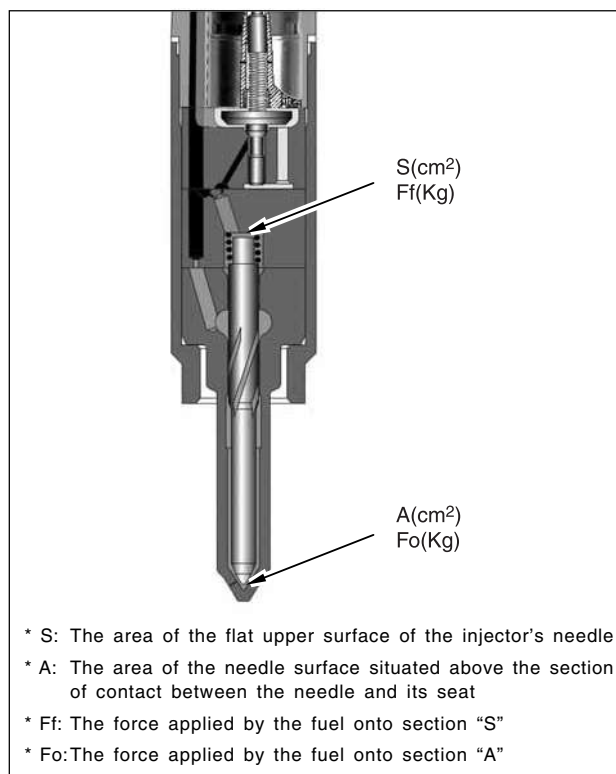
$$F_o = A \times P_{\text{rail}}$$

Since $F_f > F_o$, the needle is held in the closed position. There is no injection.

Solenoid valve control

When the solenoid valve is energized, the valve opens. The fuel contained in the control chamber is expelled through the discharge orifice known as the Spill Orifice (SPO).

As soon as $F_f > F_o$, the needle remains held against its seat and there is no injection.



Start of injection

As soon as $F_f < F_o$, or in other words:

$$P_{\text{control}} < P_{\text{rail}} * A/S$$

The needle lifts and injection begins. As long as the valve is open, the injector's needle remains lifted. When injection begins, fuel circulation is established to feed the injector. The passage of the fuel through the inlet orifice of the injector (similar to a nozzle) leads to a pressure drop which depends on the rail pressure.

When the rail pressure is at its highest (1600 bar), this pressure drop exceeds 100 bar. The pressure applied to the cone of the needle (the injection pressure) is therefore lower than the rail pressure.

End of injection

As soon as the solenoid valve is de-energized, the valve closes and the control chamber is filled. Since the needle is open, the thrust section areas situated on either side of the needle is therefore to apply different pressures to each of these faces. The pressure in the control chamber cannot exceed the rail pressure, so it is therefore necessary to limit the pressure applied to the needle's cone. This pressure limitation is achieved by the NPO orifice which produces a pressure drop when fuel is passing through it.

$$P_{\text{rail}} * S \geq (P_{\text{rail}} - \Delta P) * S$$

When static, this pressure drop is zero. When the pressure in the control chamber becomes higher than the pressure applied to the needle's cone, the injection stops.

GENERAL

A S S Y

HOUSING

I N T A K E

E X H A U S T

L U B

C O O L I N G

F U E L

C O N T R O L

S E N S O R

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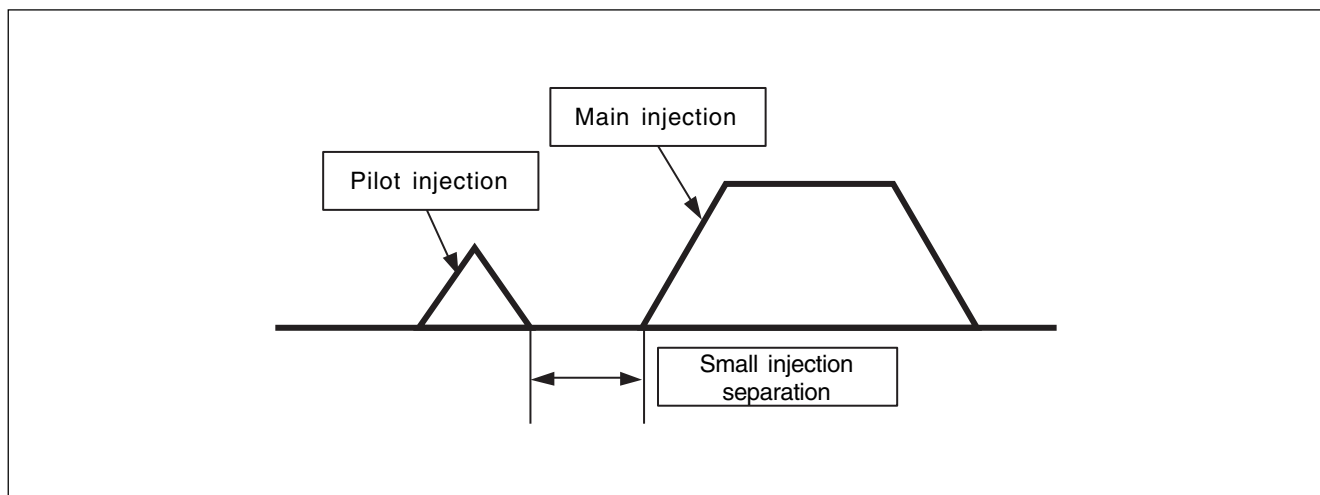
► Fuel Pressure

Fuel pressure

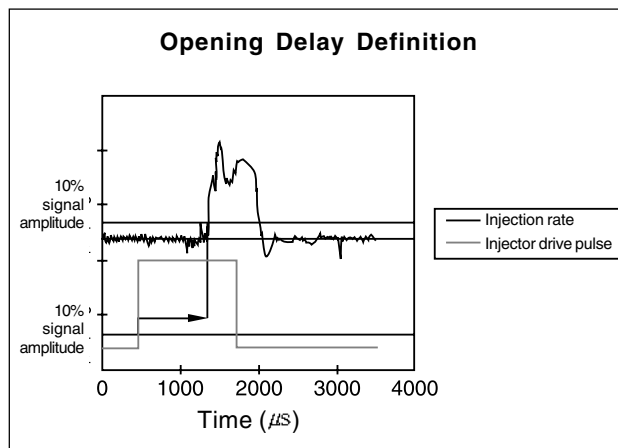
1. Minimum operating pressure: start injection over 100 bar
2. Maximum operating pressure: 1,600 bar (max. operating pressure in normal conditions)
3. Operating pressure limit: 2,100 bar

Maximum fuel volume at each injector cycle

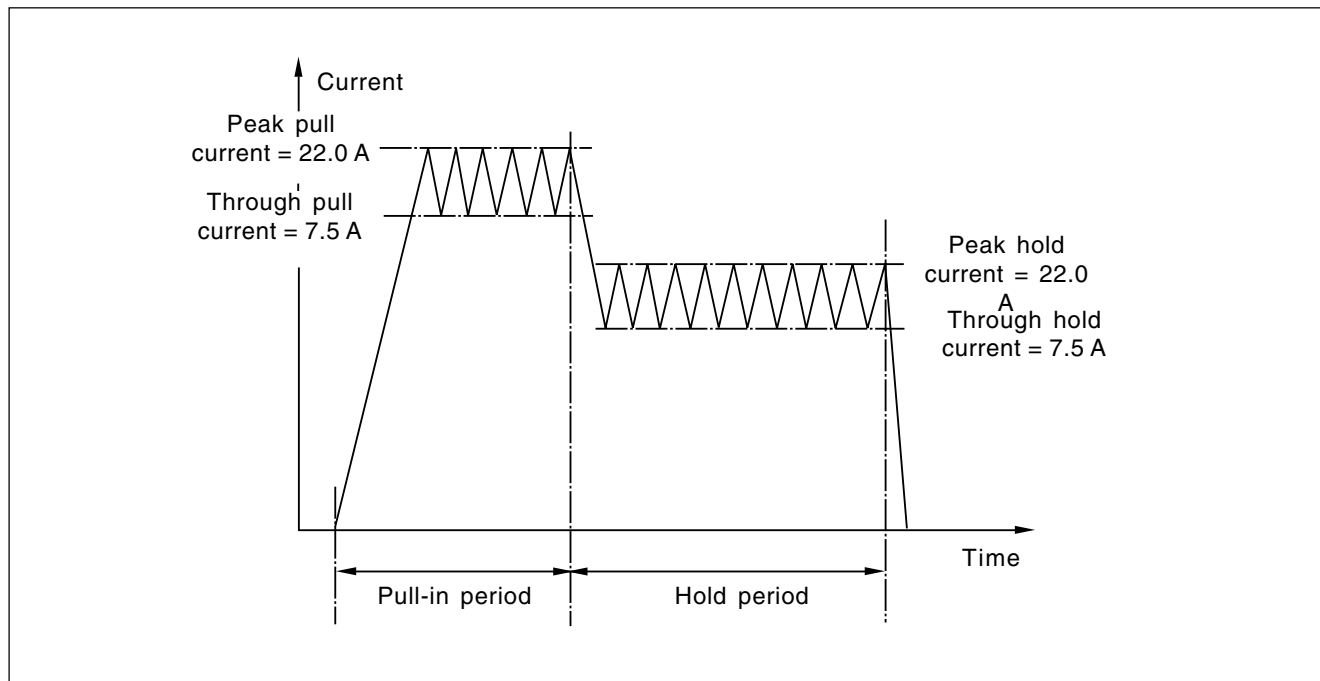
1. Pilot Injection $\leq 5 \text{ mm}^3$
2. Main Injection $\leq 85 \text{ mm}^3$ (within 200 ~ 1,600 bar)



3. Small injection separation: min. $200 \mu\text{s}$
(duration between the end of pilot injection and start of main injection)
4. Opening Delay
: Delayed time from applying operating voltage to start of injection
5. Adjustment of feedback injection volume: C2I



► Injector Control



The control current of the coil takes the following form:

1. The low current allows the Joule effect losses in the ECU and injector to be reduced. The call current is higher than the hold current because during the hold phase.
2. The air gap between the valve and the coil is reduced and the electromagnetic force to be applied to the valve can thus be reduced. It is no longer necessary to overcome the valve inertia.

NOTE

- Joule Effect: Heat capacity (H) = $0.24 I^2 RT$

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► Fuel Injection

Other than conventional diesel engine, common diesel engine use two steps injection as follows:

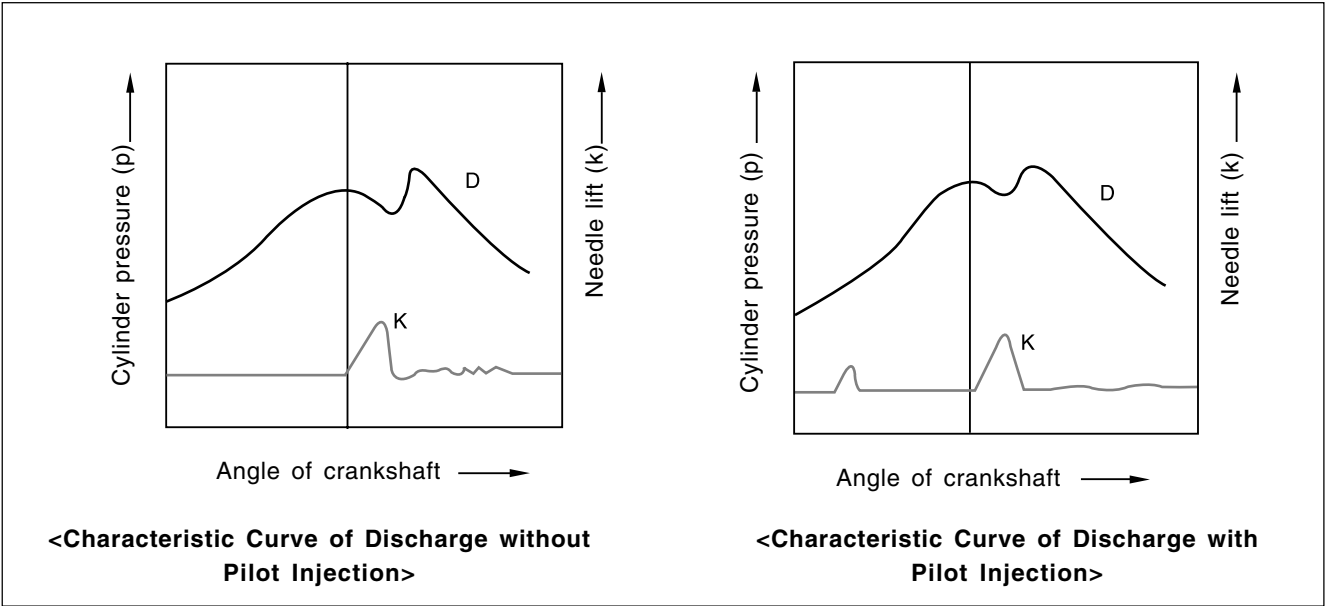
- 1. Pilot Injection
- 2. Main Injection

In above two step injection, the fuel injection volume and injection timing is calibrated according to fuel pressure and fuel temperature.

Pilot injection

Before starting main injection, a small amount of fuel is injected to help proper combustion. This injection is for reducing the engine noise and vibration.

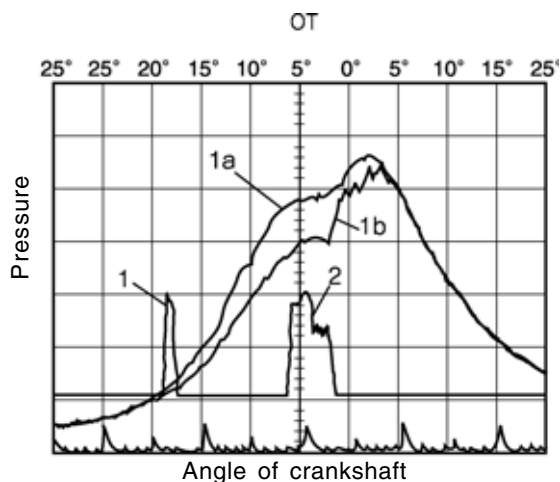
In other words, it makes the pressure increase in combustion chamber during combustion smooth to reduce the engine noise and vibration (suppressing the surging). Basic values for pilot injection are adjusted according to the coolant temperature and intake air pressure.



Main injection

Actual output from engine is achieved by main injection.

The main injection determines the pilot injection has been occurred, then calculates the injection volume. Accelerator pedal sensor, engine rpm, coolant temperature, intake air temperature and atmospheric pressure are basic data to calculate the fuel injection volume in main injection.



- 1. Pilot injection
- 2. Main injection
- 1a. Ignition pressure with pilot injection
- 2a. Ignition pressure without pilot injection

<Characteristic Curve of Combustion Chamber Pressure During Pilot Injection>

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AFFECTED VIN	

Removal and Installation

※ **Preceding Work:** Removal of engine cover

1. Disconnect the injector return hose.



NOTICE

- Plug the openings with sealing caps.

2. Remove the relevant connector for the injector.

3. Unscrew the bolts and remove the fuel pipes.

Installation Notice

Tightening torque	40 ± 4 Nm
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NOTICE

- Replace the fuel pipes with new ones.
- Plug the openings of the common rail with sealing caps.

4. Unscrew the injector holder bolts.

Installation Notice

Tightening torque	9 ± 1.0 Nm
	$190^\circ \pm 10^\circ$

Replace the bolts with new ones.

5. Disconnect the injector holder.

6. Remove the injectors with a special tool.



NOTICE

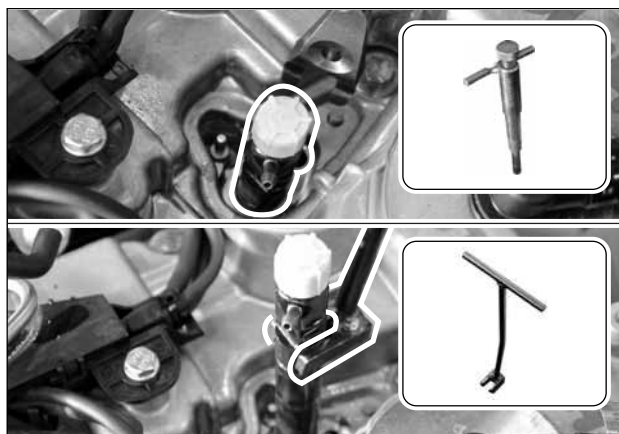
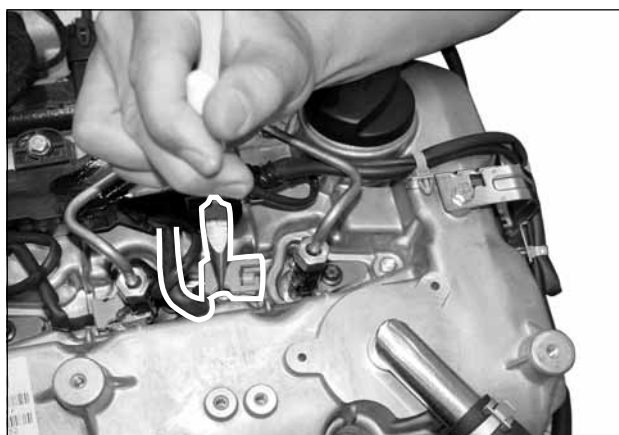
- Plug the openings of the injectors with sealing caps.
- Pull the dropped washer out from the engine with a special tool.

7. Install in the reverse order of removal.

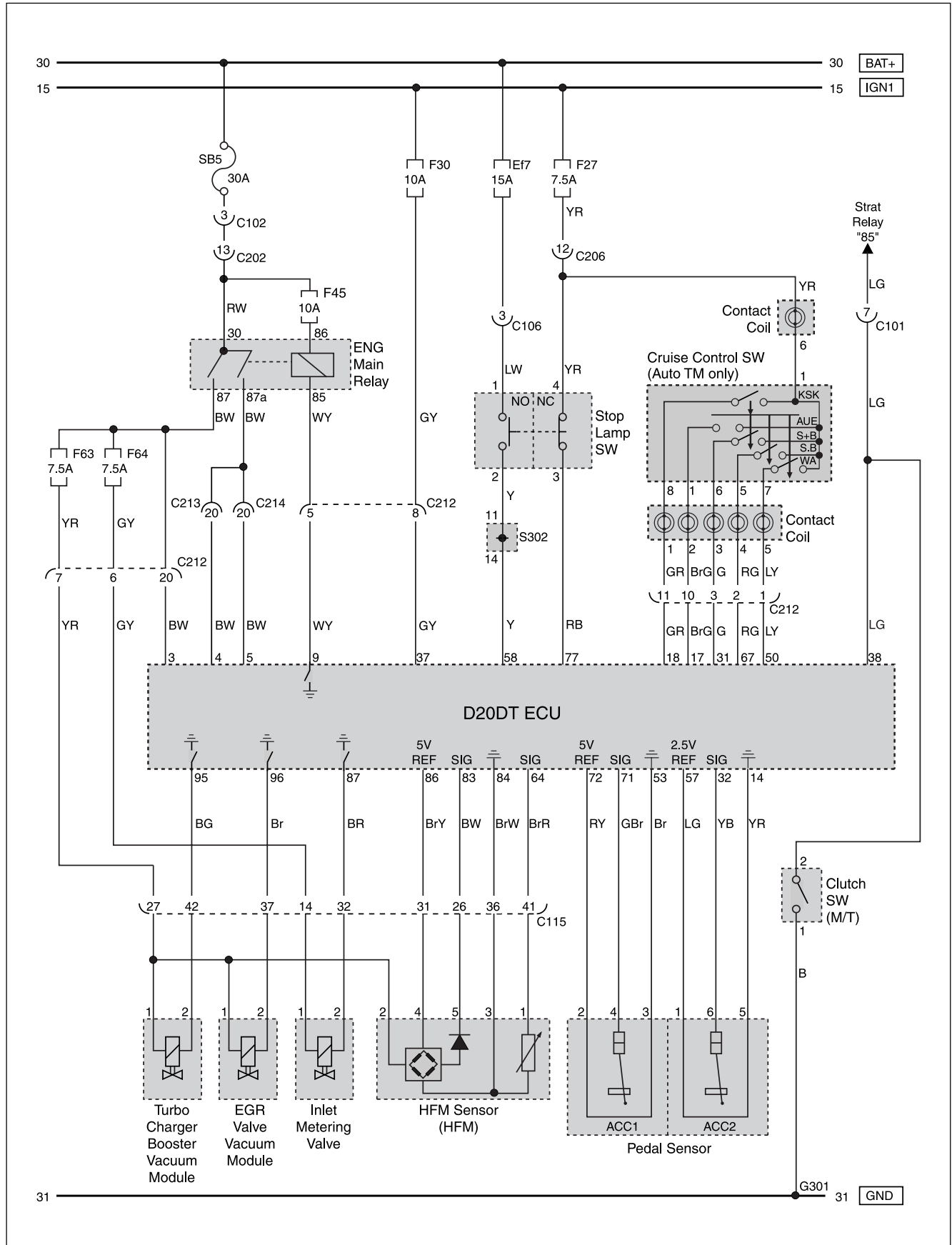


NOTICE

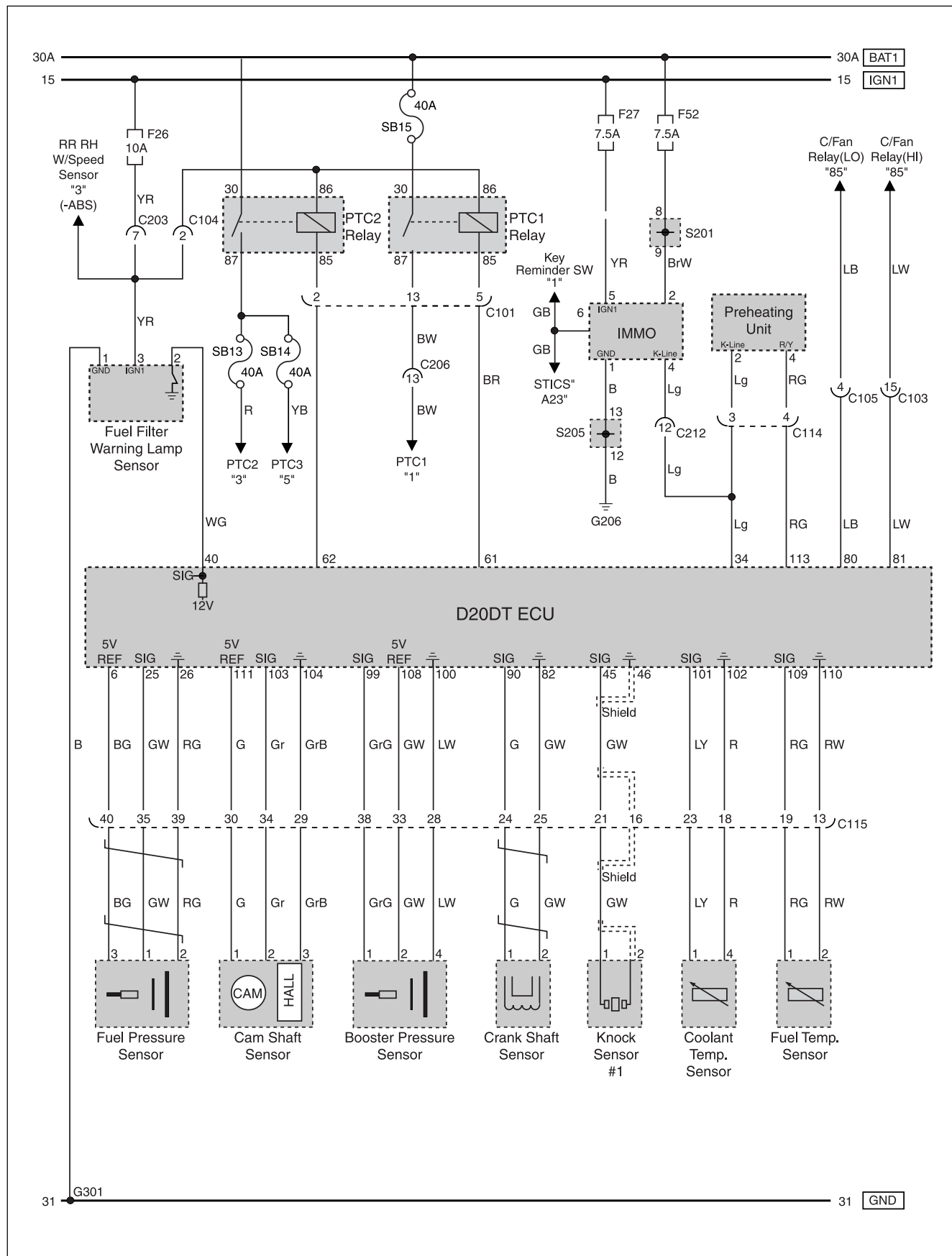
- Replace the copper washer, holder bolts and fuel supply pipes with new ones.



► Circuit Diagram

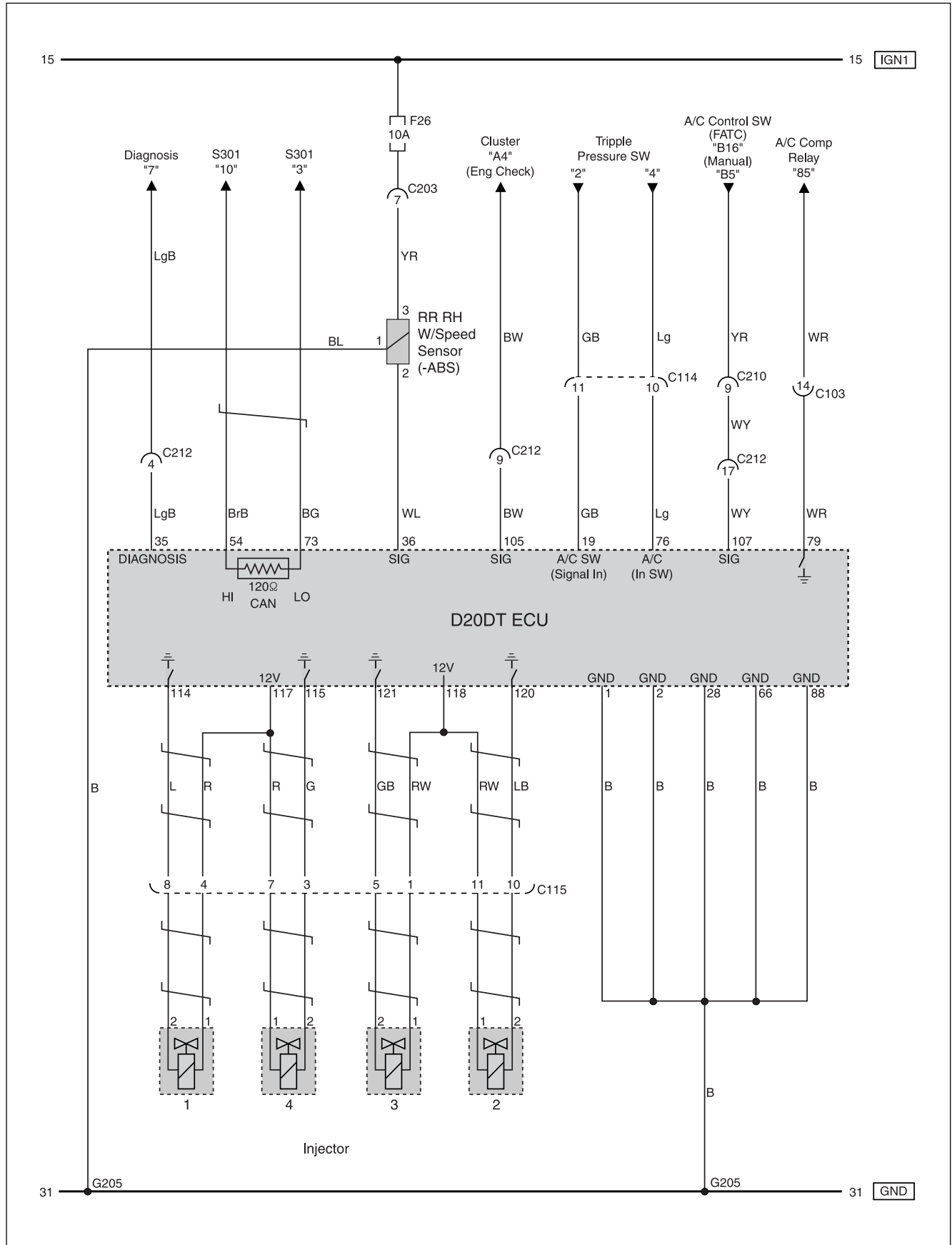


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**FUEL SYSTEM**

ACTYON SM - 2006.03

CHANGED BY	
EFFECTIVE DATE	
AFFECTED VIN	



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EFFECTIVE DATE	
AFFECTED VIN	