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EXHAUST SYSTEM - TDV8 4.4L DIESEL

DIESEL PARTICULATE FILTER - SYSTEM OPERATION AND COMPONENT DESCRIPTION (G1781010)

SYSTEM OPERATION

DIESEL PARTICULATE FILTER (DPF)

Two processes are used to regenerate the Diesel Particulate Filter (DPF); passive and active.

Passive Regeneration

Passive regeneration requires no special engine management intervention and occurs during normal engine operation. The passive regeneration involves a slow conversion of the particulate matter deposited in the DPF into carbon dioxide. This process occurs when the DPF temperature exceeds 250°C (482°F) and is a continuous process when the vehicle is being driven at higher engine loads and speeds.

During passive regeneration, only a portion of the particulate matter is converted into carbon dioxide. This is because the chemical reaction, which utilizes nitrogen dioxide, is slower than the rate of engine production of particulate matter and is effective from 250°C (482°F).

Above 580°C (1076°F) the conversion efficiency of the particulates into carbon dioxide rapidly increases. These temperatures are generally only being achieved using the active regeneration process.

Active Regeneration

Active regeneration starts when the particulate loading of the DPF reaches a threshold as monitored or determined by the DPF control software. The threshold calculation is based on driving style, distance travelled and back pressure signals from the differential pressure sensor.

Active regeneration generally occurs every 400 km (250 miles) although this is dependant on how the vehicle is driven. For example, if the vehicle is driven at low loads in urban traffic regularly, active regeneration will occur more often. This is due to the rapid build-up of particulates in the DPF than if the vehicle is driven at high speeds when passive regeneration will have occurred.

The DPF software incorporates a mileage trigger which is used as back-up for active regeneration. If active regeneration has not been initiated by a back pressure signal from the differential pressure sensor, regeneration is requested based on distance travelled.

Active regeneration of the DPF is commenced when the temperature of the DPF is increased to the combustion temperature of the particles. The DPF temperature is raised by increasing the exhaust gas temperature. This is achieved by introducing post-injection of fuel after the pilot and main fuel injections have occurred.

It is determined by the DPF software monitoring the signals from the two DPF temperature sensors to establish the temperature of the DPF.

Depending on the DPF temperature, the DPF software requests the Engine Control Module (ECM) to perform either one or two post-injections of fuel:

- The first post-injection of fuel is associated with retarded combustion to increase the temperature of the exhaust gas and therefore allow the oxidation catalyst to reach it's operational temperature.
- The second post-injection of fuel is injected late in the power stroke cycle. The fuel is not intended to combust in the cylinder, and hence unburnt fuel passes into the exhaust where it creates an exothermic event within the catalytic converter, further increasing the temperature of the DPF.

The active regeneration process takes up to 20 minutes to complete. The first phase increases the exhaust gas temperature to ensure the catalytic converter is active. The second phase further increases the DPF temperature to the optimum temperature for particle combustion. This temperature is then controlled for 15-20 minutes to ensure complete oxidation of the particles within the DPF. The oxidation process converts the carbon particles to carbon dioxide.

The active regeneration temperature of the DPF is closely monitored by the DPF software to maintain a target temperature at the DPF inlet. The temperature control ensures that the temperatures do not exceed the operational limits of the turbocharger and the catalytic converter. The turbocharger inlet temperature must not exceed 830°C (1526°F), the catalytic converter brick temperature must not exceed 800°C (1472°F) and the exit temperature must remain below 875°C (1382°F).

Air management control during DPF regeneration

The DPF air management function controls the following:

- Exhaust gas recirculation (EGR) control
- Turbocharger boost pressure control
- Intake mass air flow.

During active regeneration, the EGR operation is disabled and the closed-loop activation of the turbocharger boost controller is calculated. The air management function controls the air in the intake manifold to a predetermined mass flow. This control is required to achieve the correct in-cylinder conditions for stable and robust combustion of the post injected fuel.

The function controls the intake mass air flow by actuating the throttle and by adjustment of the turbocharger boost pressure control.

If, due to vehicle usage and/or driving style, the active regeneration process cannot take place or is unable to regenerate the DPF, the dealer can force regenerate the DPF. This is achieved by driving the vehicle until the engine is at its normal operating temperature and then driving for approximately a further 20 minutes at speeds between 60 km/h to 120 km/h (40 mph to 70 mph). It is possible that the regeneration process will occur at lower speeds, but the events may take longer at a 48 km/h (30 mph) average speed.

DPF Control

The DPF requires constant monitoring to ensure that it is operating at its optimum efficiency and does not become blocked. The ECM contains DPF software which controls the monitoring and operation of the DPF system and also monitors other vehicle data to determine regeneration periods and service intervals.

The DPF software can be divided into three separate control software functions; a DPF supervisor function, a DPF fuel management function and a DPF air management function.

These three functions are controlled by a fourth software function known as the DPF co-ordinator function. The co-ordinator function manages the operation of the other functions when an active regeneration is requested.

DPF Fuel Management Function

The DPF fuel management function controls the following:

- Timing and quantity of the four split injections per stroke (pilot, main and two post injections)
- Injection pressure and the transition between the three different calibration levels of injection.

The fuel management calculates the quantity and timing for the four split injections, for each of the three calibration levels for injection pressure, and also manages the transition between the levels.

The two post injections are required to separate the functionality of increasing in-cylinder gas temperatures and the production of hydrocarbons. The first post injection is used to generate the higher in-cylinder gas temperature while simultaneously retaining the same engine torque output produced during normal (non-regeneration) engine operation. The second post injection is used to generate hydrocarbons by allowing unburnt fuel into the catalytic converter without producing increased engine torque.

DPF Air Management Function

The DPF air management function controls the following:

- EGR control
- Turbocharger boost pressure control
- Intake mass air flow.

DPF Co-ordinator Function

The DPF co-ordinator function reacts to a regeneration request from the supervisor function by initiating and co-ordinating the following DPF regeneration requests:

- EGR cut-off - except for overrun condition
- Turbocharger boost pressure control
- Engine load increase

- Control mass air flow
- Fuel injection control.

When the supervisor function issues a regeneration request, the co-ordinator function requests EGR cut-off and a regeneration specific turbocharger boost pressure control. It then waits for a feedback signal from the EGR system confirming that the EGR valve is closed.

When the EGR valve is closed, the co-ordinator function initiates requests to increase engine load by controlling the intake mass air flow.

Once confirmation is received that intake conditions are controlled or a calibration time has expired, the co-ordinator function then changes to a state awaiting an accelerator pedal release manoeuvre from the driver. If this occurs or a calibration time has expired, the co-ordinator function generates a request to control fuel injections to increase exhaust gas temperature.

DIFFERENTIAL PRESSURE SENSOR

As the amount of particulates trapped by the DPF increases, the pressure at the inlet side of the DPF increases in comparison to the DPF outlet. The DPF software uses this comparison, in conjunction with other data, to calculate the accumulated amount of trapped particulates.

By measuring the pressure difference between the DPF inlet and outlet and the DPF temperature, the DPF software can determine if the DPF is becoming blocked and requires regeneration.

COMPONENT DESCRIPTION

DIESEL PARTICULATE FILTER (DPF)

The DPF system reduces diesel particulate emissions to negligible levels to meet current standards for:

- European stage 5 and 6 emissions
- NAS LEV3 emissions

The particulate emissions are the black fumes emitted from the diesel engine under certain load conditions. The emissions are a complex mixture of solid and liquid components with the majority of the particulates being carbon microspheres on which hydrocarbons from the engine's fuel and lubricant condense.

The DPF system comprises the following components:

- Diesel Particulate Filter (DPF)
- DPF temperature sensors

- DPF control software incorporated in the ECM
- Differential pressure sensor.

The DPF is located in the exhaust system, downstream of the catalytic converter. Its function is to trap particulate matter in the exhaust gases leaving the engine. A major feature of the DPF is its ability for regeneration. Regeneration is the burning of particulates trapped by the filter to prevent obstruction to the free flow of exhaust gasses. The regeneration process takes place at calculated intervals and is not noticeable by the driver of the vehicle.

Regeneration is most important, since an overfilled filter can damage the engine through excessive exhaust back pressure and can itself be damaged or destroyed. The material trapped in the filter is in the most part carbon particles with some absorbed hydrocarbons.

The DPF uses a filter technology based on a filter with a catalytic coating. The DPF is made from silicon carbide housed in a steel container and has excellent thermal shock resistance and thermal conductivity properties. The DPF is designed for the engine's operating requirements to maintain the optimum back pressure requirements.

The porous surface of the filter consists of thousands of small parallel channels positioned in the longitudinal direction of the exhaust system. Adjacent channels in the filter are alternately plugged at the end. This design forces the exhaust gasses to flow through the porous filter walls, which act as the filter medium. Particulate matter which are too big to pass through the porous surface are collected and stored in the channels.

The collected particulate matter, if not removed, can create an obstruction to exhaust gas flow. The stored particles are removed by a regeneration process which incinerates the particles.

Diesel Particulate Filter (DPF) Temperature Sensors

The sensors measure the temperature of exhaust gas exiting the turbocharger and before it passes through the DPF and provides the information needed to calculate the DPF temperature.

The information is used, in conjunction with other data, to estimate the amount of accumulated particulates and to control the DPF temperature.

Instrument Cluster (IC) Indications

For drivers who make regular short journeys at low speeds, it may not be possible to efficiently regenerate the DPF. In this case, the DPF software will detect a blockage of the DPF from signals from the differential pressure sensor and will alert the driver as follows:

The driver will be alerted to this condition by a message 'EXHAUST FILTER NEARLY FULL'. See 'HANDBOOK'. As detailed in the Owners Handbook, the driver should drive the vehicle until the engine is at its normal operating temperature and then drive for approximately a further 20 minutes at speeds between 60 km/h to 120 km/h (40 mph to 70 mph). It is possible that the regeneration process will occur at lower speeds, but the events may take longer at a 48 km/h (30 mph) average speed. Successful regeneration of the DPF is indicated to the driver by the 'EXHAUST FILTER NEARLY FULL' message no longer being displayed. If the DPF software detects that the DPF is still blocked, the message will continue to be displayed or an additional message 'EXHAUST FILTER FULL VISIT DEALER' will be displayed. The driver should take the vehicle to an authorized dealer to have the DPF force regenerated using an approved diagnostic system.

If, due to vehicle usage and/or driving style, the active regeneration process cannot take place or is unable to regenerate the DPF, the dealer can force regenerate the DPF. This is achieved by driving the vehicle until the engine is at its normal operating temperature and then driving for approximately a further 20 minutes at speeds between 60 km/h to 120 km/h (40 mph to 70 mph). It is possible that the regeneration process will occur at lower speeds, but the events may take longer at a 48 km/h (30 mph) average speed.

Diesel Particulate Filter (DPF) Side Effects

The following section details some side effects caused by the active regeneration process.

Engine Oil Dilution

Engine oil dilution can occur due to small amounts of fuel entering the engine crankcase during the post-injection phases. This has made it necessary to introduce a calculation based on driving style to reduce oil service intervals if necessary. The driver is alerted to the oil service by a message in the IC.

The DPF software monitors the driving style and the frequency of the active regeneration and duration. Using this information a calculation can be made on the engine oil dilution. When the DPF software calculates the engine oil dilution has reached a predetermined threshold (fuel being 7% of engine oil volume) a service message is displayed in the IC.

Depending on driving style, some vehicles may require an oil service before the designated interval. If a service message is displayed, the vehicle will be required have a full service and the service interval counter will be reset.

Fuel Consumption

During the active regeneration process of the DPF, there will be an increase in fuel consumption.

However, because active regeneration occurs infrequently, the overall effect on fuel consumption is approximately 2%. The additional fuel used during the active regeneration process is accounted for in the instantaneous and average fuel consumption displays in the IC.

DIFFERENTIAL PRESSURE SENSOR

The differential pressure sensor is used by the DPF software to monitor the condition of the DPF. Two pipe connections on the sensor are connected by pipes to the inlet and outlet ends of the DPF. The pipes allow the sensor to measure the inlet and outlet pressures of the DPF.

Aftermarket DPF Cleaning Fluids

Recent years have seen the introduction of 'DPF cleaning fluids' to (non JLR approved) aftermarket sales. These products claim to reduce the temperature that the soot reaction takes place. It should be stressed that, during the vehicle development activity, every effort is made to generate DPF regeneration temperatures whilst maintaining safe levels for all other vehicle components. Unauthorized use of the aftermarket fluids produces a significant risk to soot burn rates and DPF peak temperatures real world driving conditions. These fluids are not authorised for JLR use.

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