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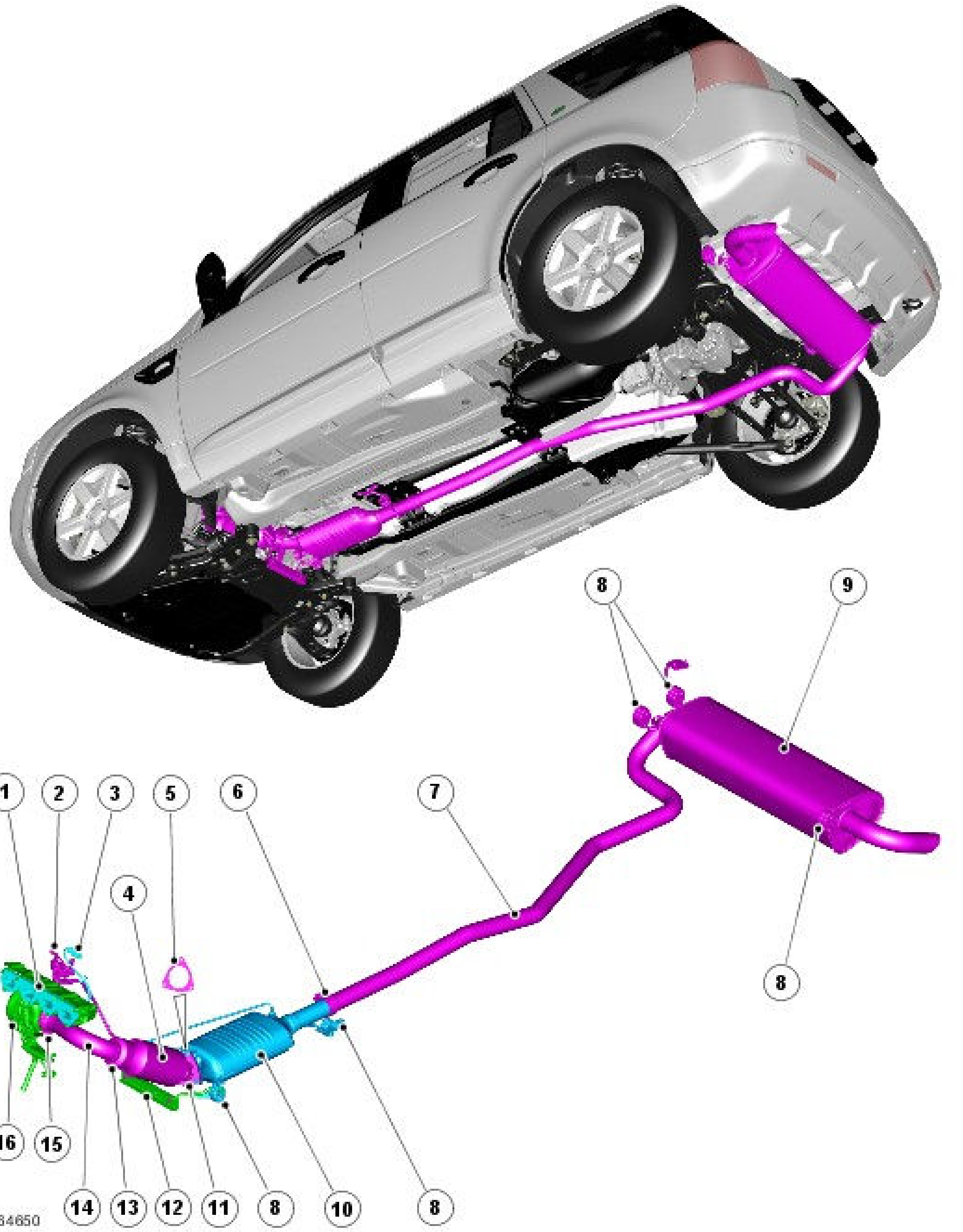
Exhaust System - 2.2L Diesel

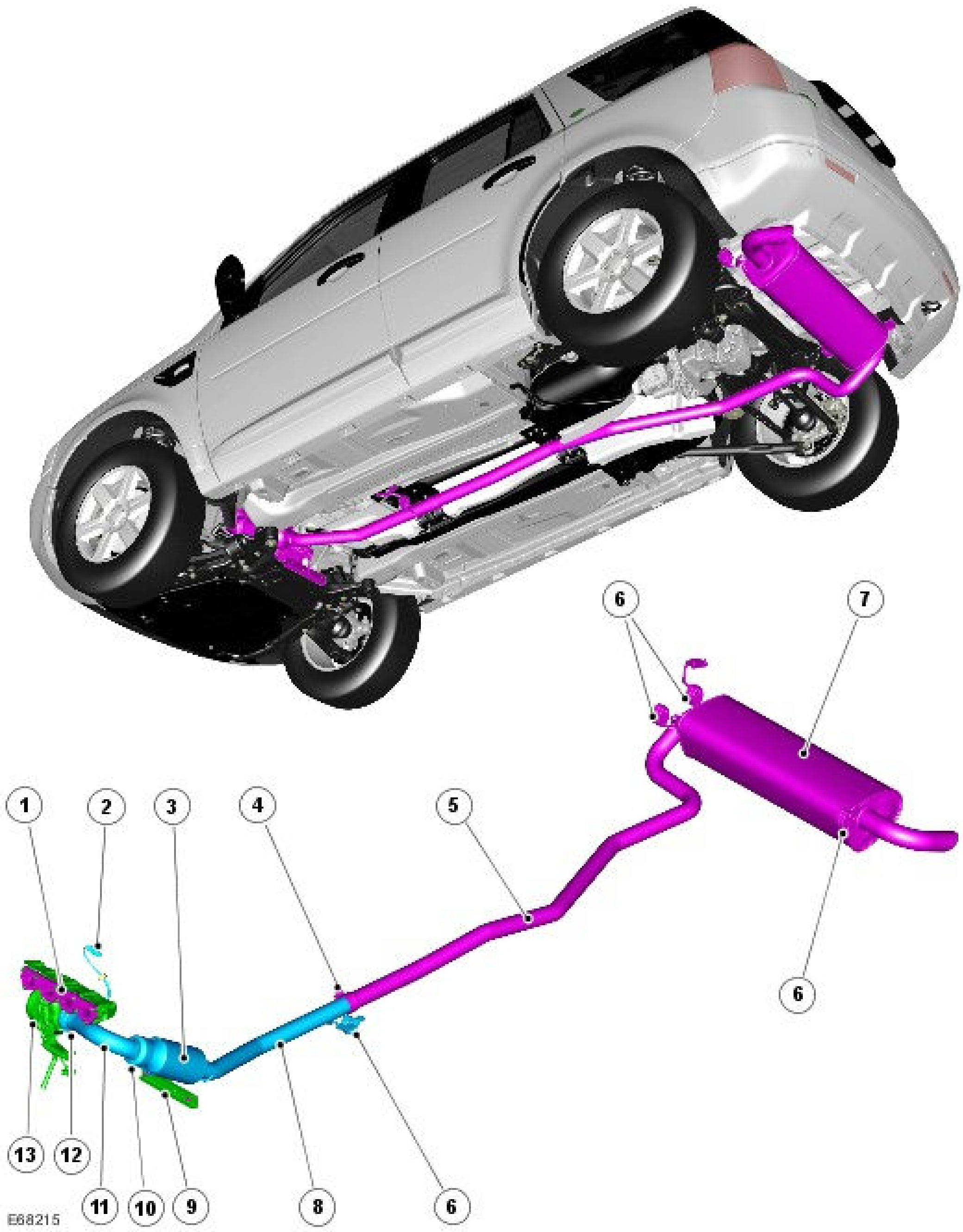
COMPONENT LOCATION - WITH DIESEL PARTICULATE FILTER



Item	Part Number	Description
1		Exhaust manifold (ref only)
2		Pressure differential sensor
3		Heated Oxygen Sensor (HO2S) (ref only)
4		Catalytic converter
5		Gasket
6		'Torca' clamp
7		Connecting pipe
8		Mounting rubber (6 off)

9		Rear muffler
10		Diesel Particulate Filter (DPF)
11		Flange
12		Body hanger
13		Decoupler
14		Outlet elbow
15		'V' clamp and gasket
16		Turbocharger (ref only)

COMPONENT LOCATION - WITHOUT DIESEL PARTICULATE FILTER



Item	Part Number	Description
1		Exhaust manifold (ref only)
2		HO2S (ref only)

3		Catalytic converter
4		'Torca' joint
5		Rear connecting pipe
6		Mounting rubber (5 off)
7		Rear muffler
8		Front connecting pipe
9		Body hanger
10		Decoupler
11		Outlet elbow
12		'V' clamp and gasket
13		Turbocharger (ref only)

OVERVIEW

The 2.2L DW12 exhaust system is fabricated from stainless steel and is supplied as two separate assemblies; a front section incorporating a catalytic converter and a rear section incorporating a rear silencer.

In some markets, the exhaust system incorporates a Diesel Particulate Filter (DPF) which allows the vehicle to exceed European Stage 4 emission standards.

The system is attached to the underside of the body with six mounting rubbers (five mounting rubbers on vehicles without DPF) which are located on mild steel hanger bars that are welded to the system. The mounting rubbers locate on corresponding hangers which are welded or bolted to the underside of the vehicle body.

FRONT SECTION

The front section has a flared end which mates with a corresponding feature on the turbocharger. The joint is secured together using a 'V' band clamp sealed with a gasket.

The flange is formed on a fabricated outlet elbow which in turn is welded to the de-coupler. The elbow incorporates a threaded boss which provides the location for the HO2S. The decoupler, which provides a flexible joint, is welded to the body of the catalytic converter.

Vehicles without DPF

A short front connecting pipe section from the catalytic converter mates with the rear connecting pipe of the system and is secured with a 'Torca' joint. A mounting rubber is located near to the catalyst and attaches to a body hanger bracket mounted on the body.

Vehicles with DPF

The catalytic converter has a flange and gasket joint which mates with a flange on the DPF. The DPF outlet has a short front connecting pipe which mates with the rear connecting pipe of the system and is secured with flange joint. Two mounting rubbers are located near to the catalyst and attach to a body hanger bracket mounted on the body.

REAR SECTION

The rear section has long connecting pipe section which mates with the front connecting pipe behind the catalyst or DPF and is secured with a 'Torca' joint. The pipe section is routed along the underside of the vehicle and connects into the Right Hand (RH) end of the rear muffler.

The rear muffler is a fabricated unit with a capacity of 29.3 liters. The muffler contains perforated baffles and tubes which reduce noise as the exhaust gases pass through the silencer. The exhaust gasses enter the muffler at the Right Hand (RH) end and exit via a pipe on the Left Hand (LH) end. The exit pipe faces the rear of the vehicle and is curved downwards to direct exhaust gasses away from the rear of the vehicle.

CATALYTIC CONVERTER

The oxidizing catalytic converter, which has a capacity of 2 liters, is fitted in the front section of the exhaust system, after the HO2S. The catalytic converter is common to vehicles with or without the DPF.

The HO2S monitors the exhaust gasses leaving the engine. The engine management system uses this information to provide accurately metered quantities of fuel to the combustion chambers to ensure the most efficient use of fuel and to minimize the exhaust emissions.

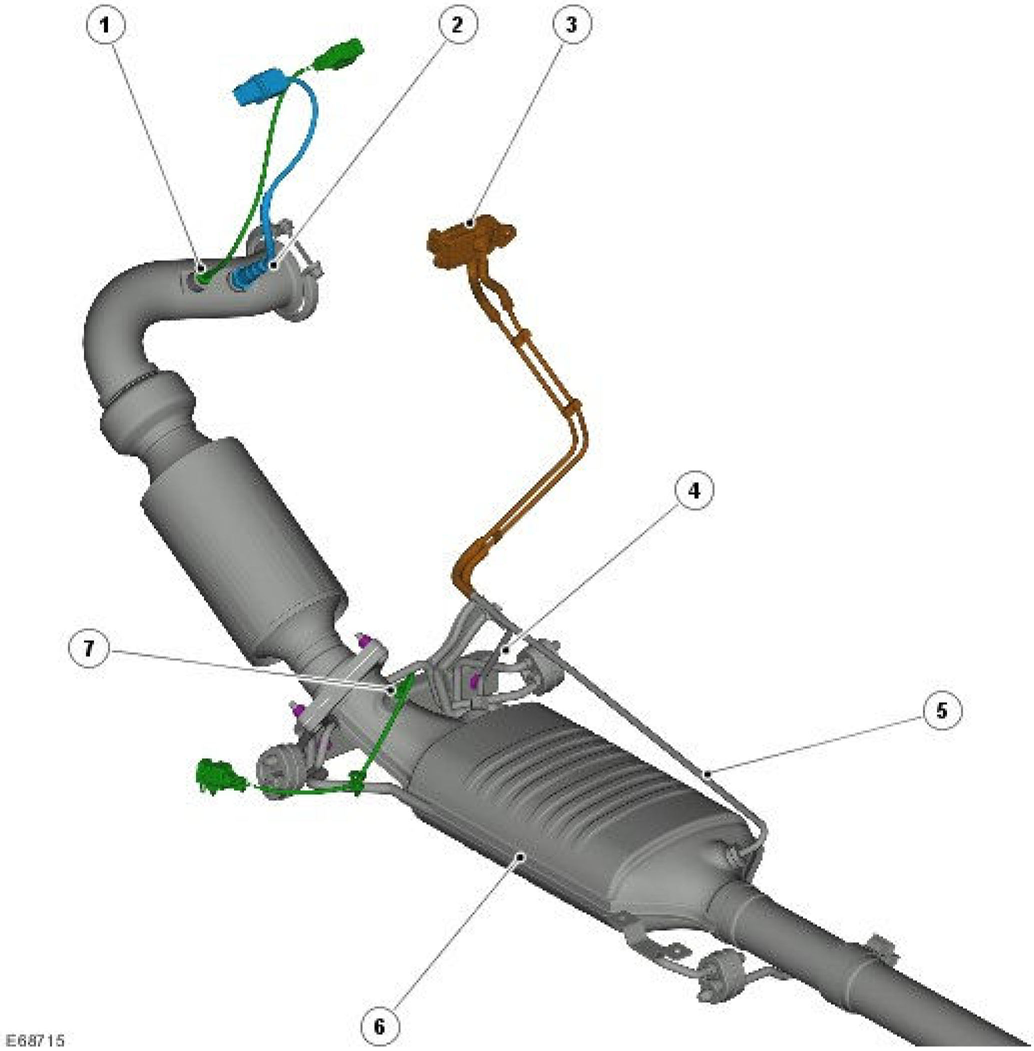
To further reduce the carbon monoxide and hydrocarbons content of the exhaust gases, a catalytic converter is integrated into the front pipe of the exhaust system. In the catalytic converter the exhaust gases are passed through honeycombed ceramic elements coated with a special surface treatment called 'washcoat'.

The washcoat increases the surface area of the ceramic elements by a factor of approximately 7000. On top of the washcoat is a coating containing platinum, which is the active constituent for converting harmful emissions into inert by-products. The platinum adds oxygen to the carbon monoxide and the hydrocarbons in the exhaust gases, to convert them into carbon dioxide and water respectively.

DIESEL PARTICULATE FILTER (if fitted)

The Diesel Particulate Filter (DPF) system reduces diesel particulate emissions to negligible levels.

DPF System Components



Item	Part Number	Description
1		Temperature sensor
2		HO2S
3		Differential pressure sensor
4		High pressure sensor pipe
5		Low pressure sensor pipe

6		Diesel particulate filter
7		Temperature sensor

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.

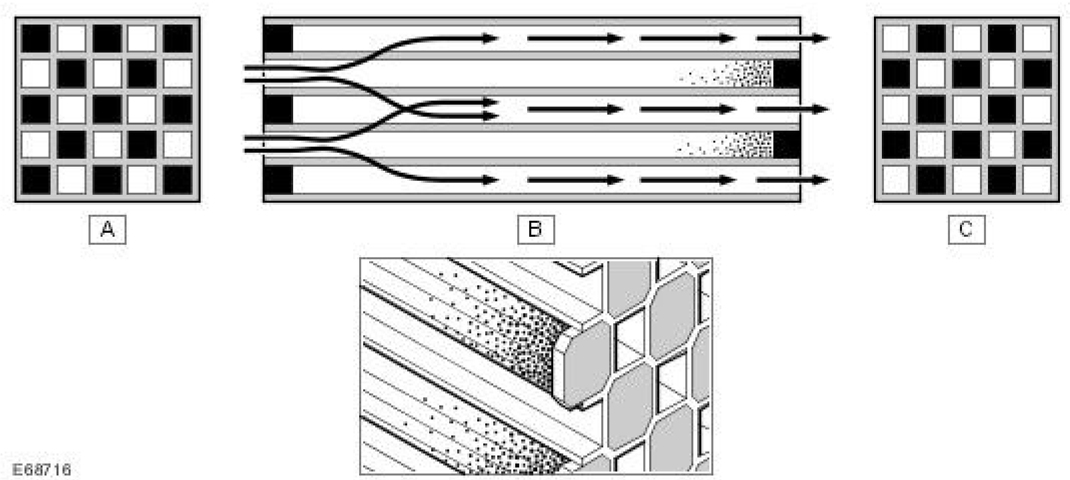
The DPF system comprises the following components:

- Diesel particulate filter
- DPF control software incorporated into the Engine Control Module (ECM)
- Differential pressure sensor.

Diesel Particulate Filter

The DPF is located in the exhaust system, downstream of the catalytic converter. 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.



Item	Part Number	Description
A		Front face showing alternate closed cells
B		Side view showing exhaust gas flow through the filter and particulate build up
C		Rear face showing alternate closed cells

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 particles are removed by a regeneration process which incinerates the particles.

The regeneration process uses NO^2 to remove the particles from the DPF. The NO^2 is generated by the catalytic converter upstream of the DPF. The catalytic converter produces temperatures in excess of 250°C (482°F) at which point the regeneration process is started.

DPF regeneration is controlled by the temperature of the exhaust gasses and the DPF. The DPF includes a wash coat to the filter surface which comprises platinum and other active components and is similar to the catalytic converter. At certain exhaust gas and DPF temperatures the wash coat promotes combustion and incineration of the particles in addition to oxidizing carbon monoxide and hydrocarbon emissions.

The exhaust gas and DPF temperatures are controlled by the DPF software located in the ECM. The DPF software monitors the load status of the DPF based on driving style, distance traveled and signals from the differential pressure sensor and temperature sensors. When the particulate loading of the DPF reaches predetermined levels, the DPF is actively regenerated by adjusting, in conjunction with the ECM, various engine control functions such as:

- fuel injection
- intake air throttle
- exhaust gas recirculation
- turbocharger boost pressure control.

The regeneration process is possible because of the flexibility of the common-rail fuel injection engine which provides precise control of fuel flow, fuel pressure and injection timing which are essential requirements to promote the efficient regeneration process.

Two processes are used to regenerate the 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 is active when the DPF temperature reaches 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 due to the chemical reaction process which is only effective within the normal operating temperature range of 250°C to 500°C (482°F to 932°F).

Above this temperature range the conversion efficiency of the particulates into carbon dioxide increases as the DPF temperature is raised. These temperatures can only be 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 traveled and back pressure signals from the differential pressure sensor.

Active regeneration generally occurs every 450 miles (725 km) 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 traveled.

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.

This 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 ECM to perform either one or two post-injections of fuel:

- The first post-injection of fuel retards combustion inside the cylinder which increases the temperature of the exhaust gas.
- The second post-injection of fuel is injected late in the power stroke cycle. The fuel partly combusts in the cylinder, but some unburnt fuel also 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 approximately 20 minutes to complete. The first phase increases the DPF temperature to 500°C (932°F). The second phase further increases the DPF temperature to 600°C (1112°F) which is the optimum temperature for particle combustion. This temperature is then maintained for 15-20 minutes to ensure complete incineration of the particles within the DPF. The incineration process converts the carbon particles to carbon dioxide and water.

The active regeneration temperature of the DPF is closely monitored by the DPF software to maintain a target temperature of 600°C (1112°F) 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) and the catalytic converter brick temperature must not exceed 800°C (1472°F) and the exit temperature must remain below 750°C (1382°F).

During the active regeneration process the following ECM controlled events occur:

- The turbocharger is maintained in the fully open position. This minimizes heat transmission from the exhaust gas to the turbocharger and reduces the rate of exhaust gas flow allowing optimum heating of the DPF. If the driver demands an increase in engine torque, the turbocharger will respond by closing the vanes as necessary.
- The throttle is closed as this assists in increasing the exhaust gas temperature and reduces the rate of exhaust gas flow which has the effect of reducing the time for the DPF to reach the optimum temperature.
- The Exhaust Gas Recirculation (EGR) valve is closed. The use of EGR decreases the exhaust gas temperature and therefore prevents the optimum DPF temperature being achieved.

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 either driving the vehicle until the engine is at its normal operating temperature and then driving for a further 20 minutes at speeds of not less than 30 mph (48 km/h) or by connecting a Land Rover approved diagnostic system to the vehicle which will guide the technician through a regeneration procedure to clean the DPF.

Diesel Particulate Filter 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 modules; a DPF supervisor module, a DPF fuel management module and a DPF air management module.

These three modules are controlled by a fourth software module known as the DPF co-ordinator module. The co-ordinator module manages the operation of the other modules when an active regeneration is requested. The DPF supervisor module is a sub-system of the DPF co-ordinator module.

DPF Fuel Management Module

The DPF fuel management module controls the following functions:

- 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 above functions are dependant on the condition of the catalytic converter and the DPF.

The controlled injection determines the required injection level in addition to measuring the activity of the catalytic converter and the DPF. 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 Module

The DPF air management module controls the following functions:

- EGR control
- Turbocharger boost pressure control
- Intake air temperature and pressure control.

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

The module controls the intake air temperature by actuating the EGR throttle and by adjustment of the turbocharger boost pressure control.

DPF Co-ordinator Module

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

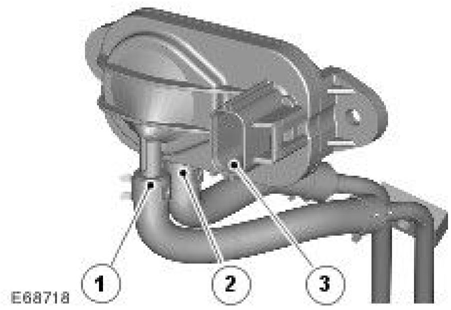
- EGR cut-off
- Turbocharger boost pressure control
- Engine load increase
- Control of air pressure and temperature in the intake manifold
- Fuel injection control.

When the supervisor module issues a regeneration request, the co-ordinator module 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 module initiates requests to increase engine load by controlling the intake air temperature and pressure.

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

Differential Pressure Sensor



Item	Part Number	Description
1		High pressure connection
2		Low pressure connection
3		Electrical connector

The differential pressure sensor is located in the engine compartment, on the lower RH side of the bulkhead. The sensor is located on two studs and secured with nuts.

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.

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 conduction 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.

Differential Particulate Filter Temperature Sensors

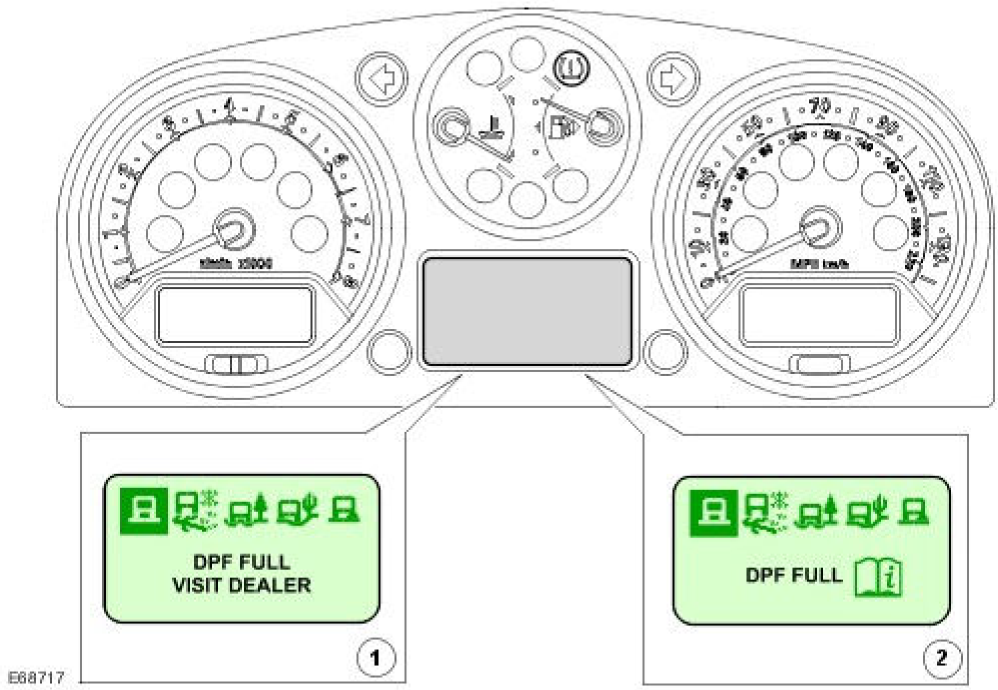
Two temperature sensors are used in the DPF system. One is located in the turbocharger outlet elbow, adjacent to the HO2S and the second sensor is located in the DPF inlet.

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 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.



Item	Part Number	Description
1		'DPF FULL' message
2		'DPF FULL VISIT DEALER' message

The driver will be alerted to this condition by a message 'DPF FULL' accompanied by a handbook symbol. 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 a further 20 minutes at speeds of not less than 30 mph (48 km/h). Successful regeneration of the DPF is indicated to the driver by the 'DPF FULL' message no longer being displayed. If the DPF software detects that the DPF is still blocked, the message will change to 'DPF FULL VISIT DEALER', the driver should take the vehicle to an authorized dealer to have the DPF force regenerated.

Diesel Particulate Filter 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 instrument cluster.

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 instrument cluster.

Depending on driving style, some vehicles may require an oil service before the designated interval. If an 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 and for limited periods of time, 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 instrument cluster.