SERVICE INFORMATION BULLETIN

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REFERENCE: SI0144
SUBJECT: **SUBARU DIESEL PARTICULATE FILTER OPERATION, REGENERATION AND DIAGNOSIS**

Recently, Subaru has introduced 2 Diesel models to its line up. Outback 2.0D and Forester 2.0D. These models are both designed for the strict Euro 5 emissions standard, and therefore include a Closed Diesel Particulate Filter (DPF) system.

The operation and diagnosis of this system can be quite involved. This bulletin is designed to provide a clear understanding of the purpose, normal operation and diagnosis of the closed DPF system.

What are Diesel Particulates?

Under engine operating conditions such as cold start, acceleration and high load the combustion process of the common rail diesel engine is incomplete, resulting in an increased formation of soot particles. These microscopically small particles have a diameter of only approx. 0.05 µm

Soot itself has no harmful effect on the human organism. Hydrocarbons originating from the fuel and lubricants, as well as water and sulphates, attach themselves to these granulates, increasing their size to 0.09µm. In this way the harmful soot particles are formed.

The human nose and bronchial tubes are not able to filter out particles smaller than 2.5 µm (for comparison: a hair is about 70 µm thick). Thus, the particles can penetrate through the airways deep into the lungs and pose a health threat especially to children and adults with certain medical conditions. Soot particles are suspected of triggering allergies and even cancer. This is especially true of the smallest particles measuring between 0.1...1.0 µm.

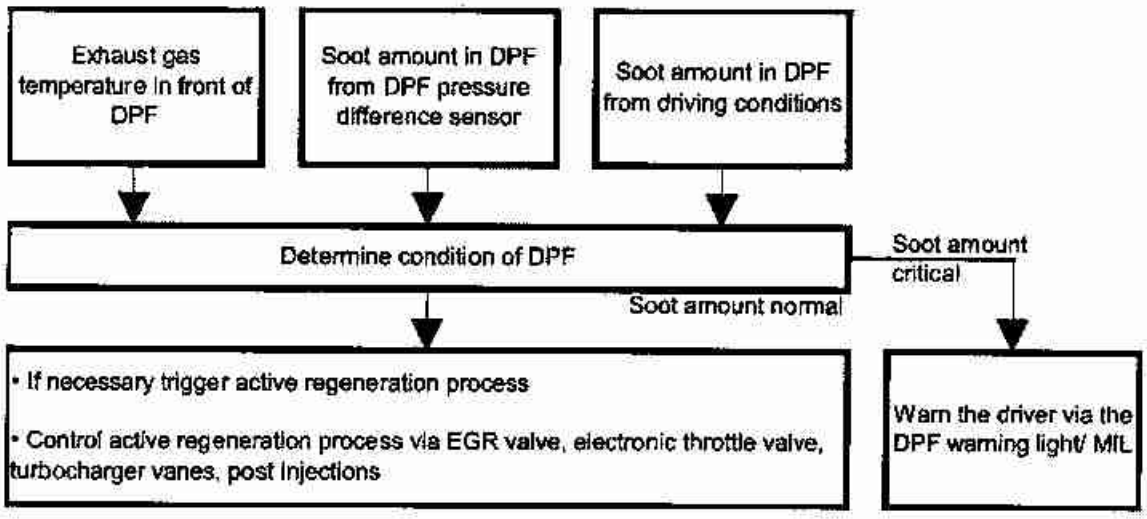
The following sample calculation shows the benefit of a closed diesel particulate filter system: A modern 2.0 L common rail diesel engine without diesel particulate filter emits on average approx. 4 kg of soot over a mileage of 100,000 km. With a closed diesel particulate filter it emits less than 250 g over the same mileage, which is a reduction of approx. 95 %.

Regeneration Control

In order for the vehicle to carry out its self maintenance of the closed DPF, certain driving conditions must be met to generate enough heat in the exhaust system to combust the harmful soot particles. This process is called regeneration.

There are four types of regeneration processes. Thermal, Passive, Active and Forced.

The basic inputs to the ECM for the calculation of the regeneration control are shown in the flowchart below.



The ECM receives information about the soot amount accumulated in the diesel particulate filter from the DPF pressure difference sensor. In addition, the ECM calculates the soot amount in the filter from the driving conditions of the vehicle.

Depending on the actual soot amount and the exhaust gas temperature in front of the diesel particulate filter, the ECM determines the soot amount percentage of the DPF.

The ECM triggers an active regeneration process when the soot amount in the DPF has reached a certain limit (65%) AND when the exhaust gas temperature in front of the diesel particulate filter is high enough to burn off the soot particles.

Thermal Regeneration

Thermal regeneration is a process where the soot particles stored in the Diesel particulate filter are combusted (Burnt off) by extremely high temperatures. The temperature range of thermal regeneration is between 550'C and 700'C.

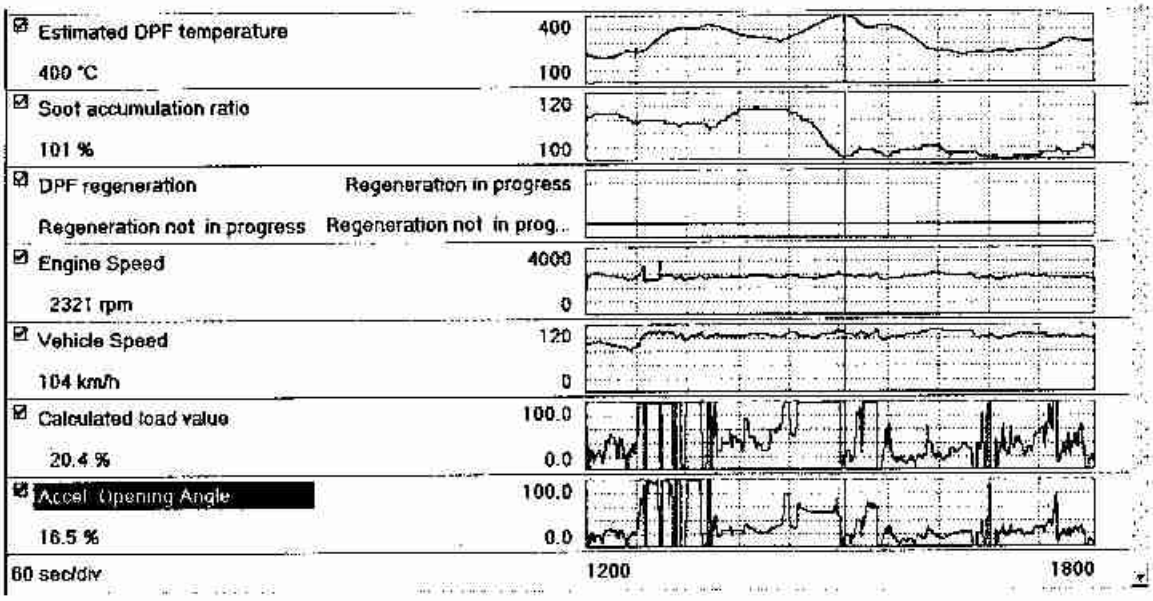
These temperatures are rarely seen during normal urban cycle driving, however driving under high load for extended periods (towing, large throttle openings up extended hill climbs) can generate enough combustion temperature to promote thermal regeneration.

Because the ECU does not have an affect to thermal regeneration process, it is not added to the regeneration count value stored in the engine ECU.

Passive Regeneration

During passive regeneration the Nitrous Oxides (NO2) produced by the diesel oxidation catalyst are used to combust (burn off) the soot particles. This process takes place at an exhaust gas temperature between 300...450 °C.

During normal light throttle driving the exhaust gas temperature varies between 150 °C (urban driving) and 400 °C (inter-urban driving). If the exhaust gas temperature is continually held around 150'C to 250'C, then the soot level will continue to increase in the closed DPF. If driving conditions increase exhaust gas temperature (Eg: increased engine load, maintaining engine speed in the torque band) the soot level will decrease as the passive regeneration process starts.



Active Regeneration

During Active regeneration the oxygen (O2) in the exhaust gas is used to combust the soot particles. This process takes place at an exhaust gas temperature between 550...700 °C. However, during normal driving this temperature is practically not reached.

Since the temperature of the exhaust gas must be raised by intervention from the ECM for the regeneration process to start, this regeneration type is called 'active regeneration'.

If the engine operating conditions are suitable to start an active regeneration, the ECM performs some or all of the following measures to increase the combustion temperature, which in turn leads to an increase of the exhaust gas temperature:

- The EGR valve is closed fully to raise the combustion temperature by increasing the oxygen proportion of the cylinder charge
- The electronic throttle valve is closed partially to increase the combustion temperature by throttling the intake air
- The turbocharger vanes are moved to the open position to raise the combustion temperature by reducing the boost pressure

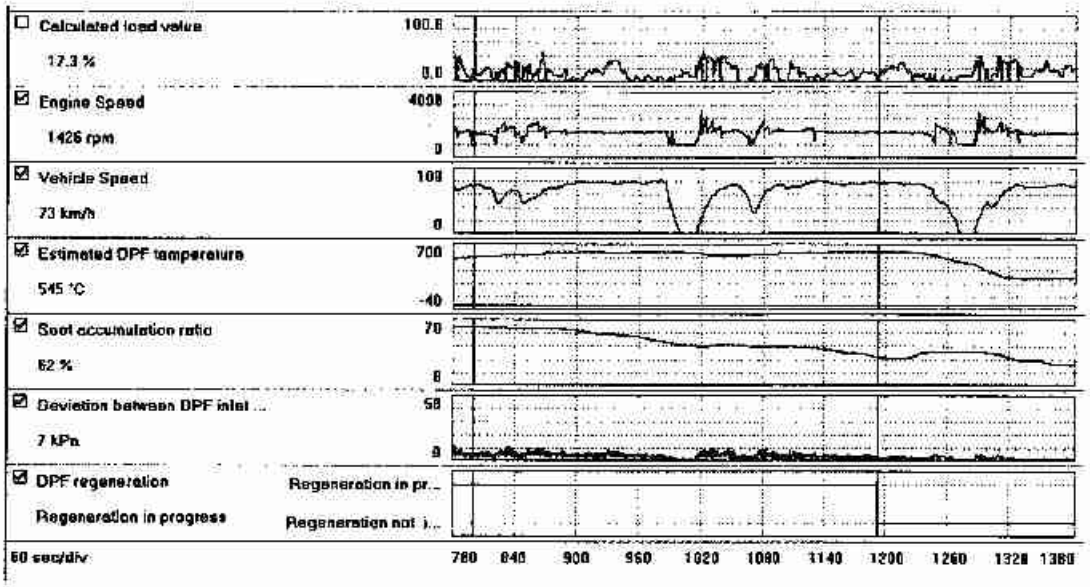
Additionally, in order to directly influence the exhaust gas temperature, the fuel injectors perform one or two post-injections. Due to the late injection timing the injected fuel does not burn in the combustion chamber, but only evaporates. The evaporated fuel enters the exhaust system and burns in the heated up diesel oxidation catalyst, increasing the exhaust gas temperature significantly.

The active regeneration process is cancelled when the soot accumulation ratio has decreased to 30 %. However, the minimum duration of the active regeneration process is approx. 12 min, i.e. even if the soot accumulation ratio has fallen to 30 % before this time has elapsed, the regeneration will be continued. When regeneration has started, the ECM will try to complete the process regardless of the engine operating conditions. However, when the engine is shut off the regeneration process is stopped. In this case, the process is re-started once the operating conditions for active regeneration are met again.

As soon as the target temperature of more than 550 °C is reached, the active regeneration process starts and the soot particles in the diesel particulate filter are burnt off. The ECM continuously monitors the regeneration process using the signals from the DPF pressure difference sensor and from the exhaust-gas temperature sensors.

Control over the regeneration process is critical, since the silicon carbide ceramics of the diesel particulate filter are damaged by glazing when the temperature exceeds 1000 °C.

Moreover, the catalytic coating of the diesel oxidation catalyst and diesel particulate filter could be damaged due to the high temperature.

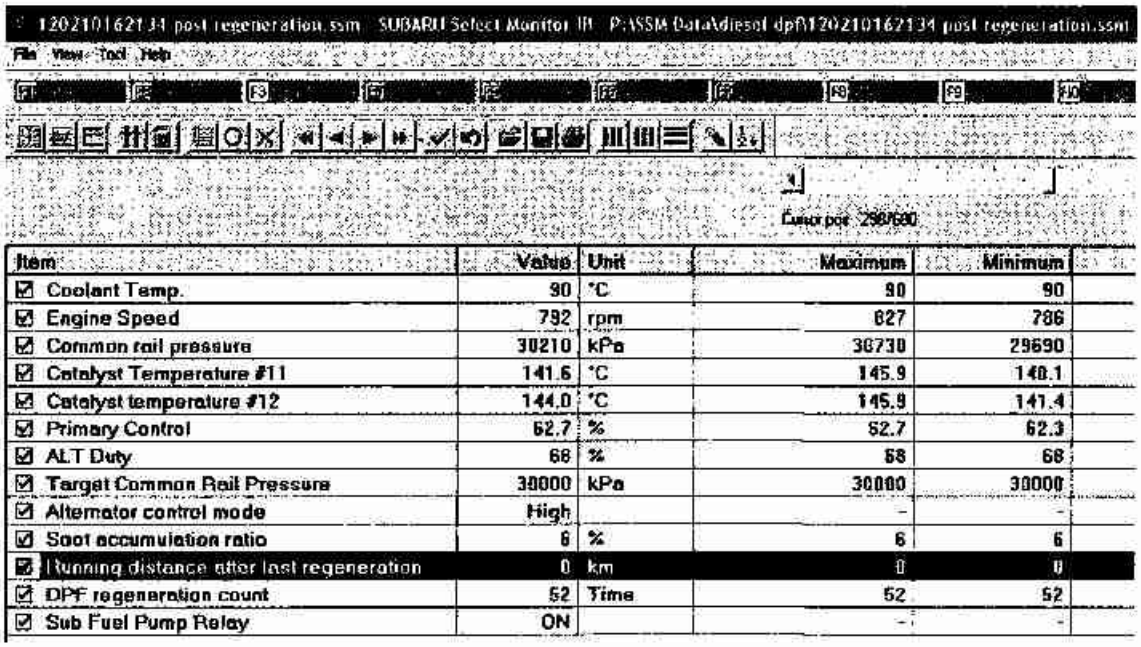


NOTE: During the active regeneration process the drivability, engine revolutions, engine sound and exhaust gas smell may change. In addition, it is possible for white smoke to be emitted from the exhaust tailpipe during regeneration. These are side effects of the regeneration process and should not be considered as a concern.

Forced Regeneration

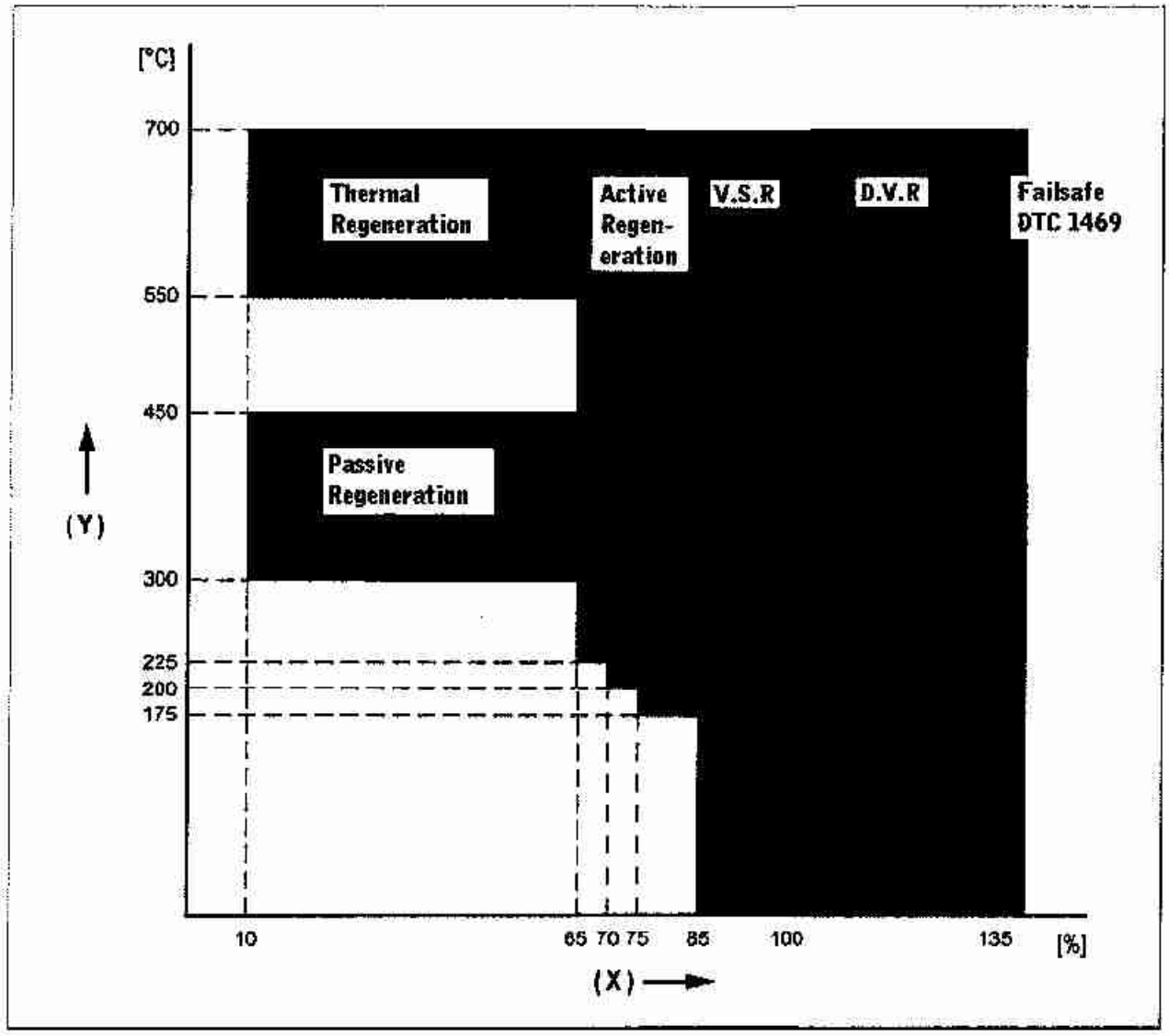
Forced regeneration is basically similar to the active regeneration process, meaning the chemical reaction and the exhaust gas temperature range for burning off the soot particles is the same.

Because the regeneration process is not initiated by the ECM during driving, but forcibly initiated by Subaru technicians with SSM III diagnostic interface, this regeneration type is called 'forced regeneration'.



Item	Value	Unit	Maximum	Minimum
Coolant Temp.	90	°C	90	90
Engine Speed	792	rpm	827	786
Common rail pressure	30210	kPa	30730	29690
Catalyst Temperature #11	141.6	°C	145.9	140.1
Catalyst temperature #12	144.0	°C	145.9	141.4
Primary Control	62.7	%	62.7	62.3
ALT Duty	68	%	68	68
Target Common Rail Pressure	30000	kPa	30000	30000
Alternator control mode	High		-	-
Soot accumulation ratio	6	%	6	6
Running distance after last regeneration	0	km	0	0
DPF regeneration count	52	Time	52	52
Sub Fuel Pump Relay	ON		-	-

DPF Regeneration Map



Warning Light Strategy

The warning light strategy to inform the driver of the soot amount in the diesel particulate filter is described in the following table:

Item	Soot accumulation warning strategy				
Soot accumulation ratio	65%	85%	100%	135%	
Operating mode	—	—	Vehicle speed request	Dealer visit request	Limp home mode
DPF warning light	—	—	Illuminates	Flashes	
MIL	—	—	—	—	Illuminates
Output restriction	—	—	—	—	Max. 160 km/h
DTC stored in ECM	—	—	—	—	P1469
Customer action	—	—	Drive vehicle at a vehicle speed of min. 60 km/h (engine speed 1800...2500 1/min, engine warmed up) for min. 15 min	Bring vehicle to dealer	
DPF active regeneration	—	Enabled		Disabled	
DPF forced regeneration	—	Enabled		Enabled	Disabled
Dealer action	—	—		Perform forced regeneration	Replace DPF and reset the DPF-related learning values in the ECM

Vehicle Speed Request

The vehicle speed request signals to the driver via the illuminated DPF warning light, that they must enable an active regeneration of the diesel particulate filter by driving the vehicle under the following conditions for at least 15 minutes duration:

- Vehicle speed: Above 60 km/h
- Engine speed: 1800...2500rpm min (driving in 4th, 5th or 6th gear) (Most suitable is 4th gear above 2,000 rpm with steady throttle.)
- Engine is completely warmed up

NOTE: Do not accelerate hard during the active regeneration process.

The ECM triggers the vehicle speed request, when the soot accumulation ratio in the diesel particulate filter has reached 85 %. When the soot accumulation ratio has fallen to 56 % during active regeneration, the DPF warning light turns off. However, even though the warning light

turns off, the regeneration process is continued until the cancellation conditions for active regeneration are met.

NOTE: If the driver complains that the DPF warning light illuminates frequently, he must be informed to change the driving method (such as driving the vehicle at high engine load for a longer distance), so that regeneration of the diesel particulate filter is enabled.

In testing conducted by Subaru Australia's Technical department, the below vehicle speed / engine speed gear shift points are recommended for the best compromise between vehicle performance, fuel consumption and maintaining exhaust temperature to reduce soot accumulation.

Recommended Driving style			
Gear Position		Up shift Speed Minimum	Engine speed Minimum
1st	0	24 Kph	2600 rpm
2nd	25 Kph	40 Kph	2200 rpm
3rd	41 Kph	64 Kph	2200 rpm
4th	65 Kph	82 Kph	2100 rpm
5th	83 Kph	105 Kph	2000 rpm
6th	106 Kph	110 Kph	

Dealer Visit Request

The dealer visit request signals to the driver via the flashing DPF warning light, that they must bring the vehicle to the dealer.

The ECM triggers the dealer visit request, when the soot accumulation ratio in the diesel particulate filter has reached 100 %. In this case, the active regeneration is disabled and a forced regeneration of the diesel particulate filter must be performed.

If the vehicle is driven with the dealer visit request triggered and the soot particles are burnt off because passive or thermal regeneration is taking place, the DPF warning light may turn off when the soot accumulation ratio is below 65%.

NOTE: Forced regeneration of the diesel particulate filter due to incorrect driving style or driving patterns is not covered by warranty.

Limp Home Mode

The limp home mode ensures that the vehicle can be driven to the next Subaru retail service site when there is a malfunction on the diesel particulate filter system. In this case, the DPF warning light flashes, the MIL illuminates and DTC P1469 is stored in the ECM.

The ECM triggers limp home mode when the soot accumulation ratio in the diesel particulate filter has reached 135 %. In this case, the fuel injection amount is reduced, so that the maximum vehicle speed is restricted to 160 km/h. Thus, the soot emission of the engine and hence the soot amount entering the DPF is reduced. Furthermore, the exhaust gas recirculation is deactivated by closing the EGR valve and opening the electronic throttle body, further reducing the soot emission of the engine.

If limp home mode is triggered, active regeneration as well as forced regeneration is disabled to prevent damage of the diesel particulate filter by a violent regeneration following an over accumulation of soot. In this case, the diesel particulate filter must be replaced and the DPF related learning values in the ECM must be reset.

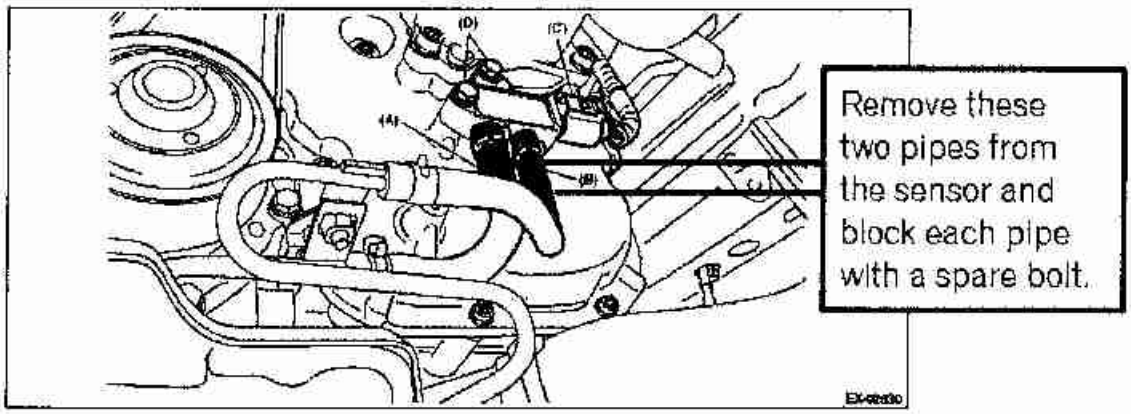
DPF Over-ride Reset

If the vehicle is continually driven while the soot accumulation is increasing, the level of soot accumulation may reach the point where the DTC 1469 is logged (135% and above). At this point, the ECU will lock out the forced regeneration option as damage may have occurred to the Diesel particulate filter and it may require replacement.

In SAP testing, it has been found that by driving the vehicle while increasing DPF and catalyst temperature, the soot can be thermally burnt off. This may require a road test where the vehicle can be driven uphill in the peak engine torque band for a time period of 2 – 3 minutes. In this time the catalyst and DPF temperature should increase to a level where thermal regeneration takes place.

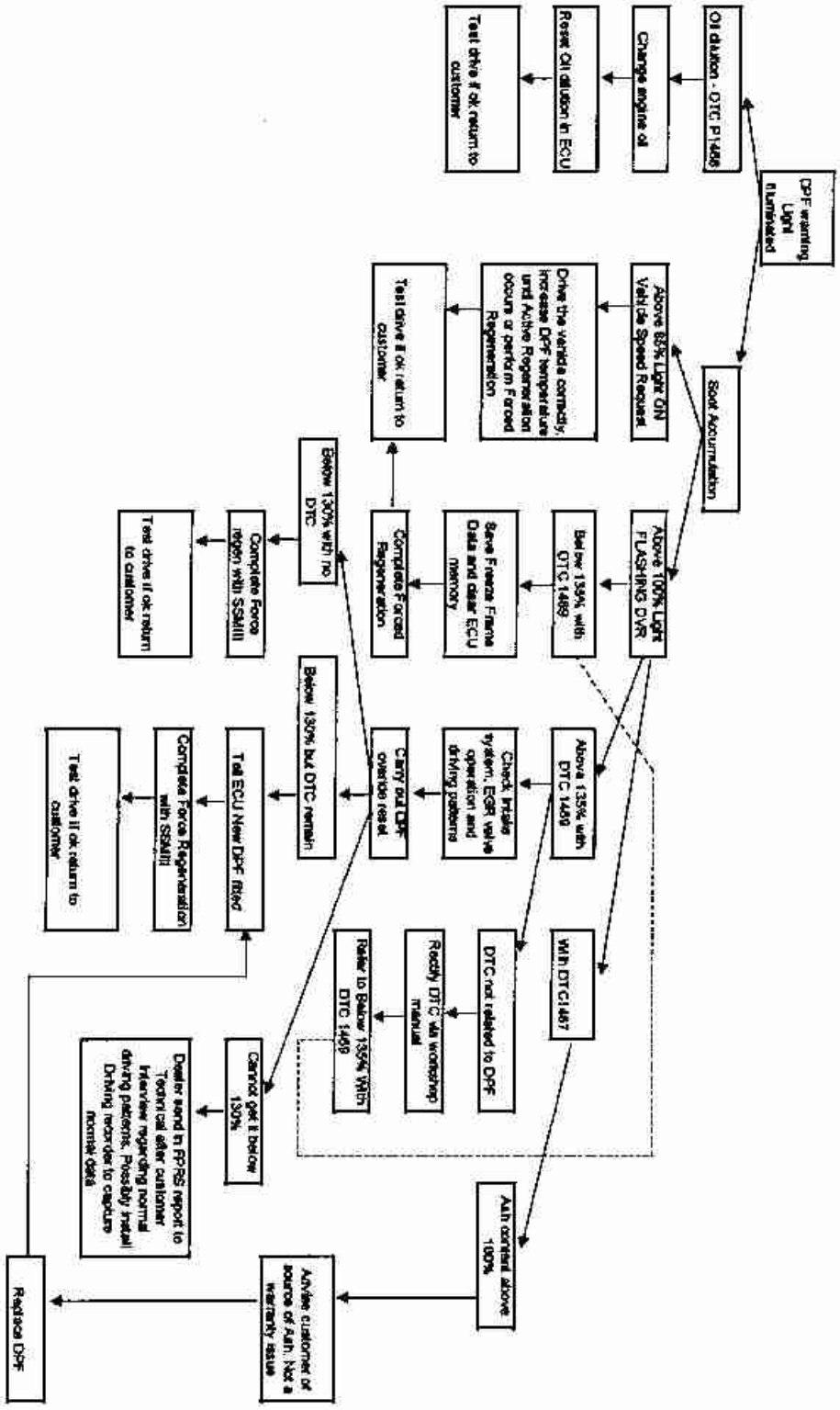
If this driving procedure is not a practical repair method, then it is possible to perform an over – ride reset of the DPF regeneration lock out.

- Locate the upstream and downstream pressure pipes at the DPF pressure difference sensor.
- Remove the two pipes as displayed in the below diagram, and block with correctly sized bolts.



- Start the engine and idle for 1 minute, cycle the engine speed between idle and 2500rpm repeatedly for 1 minute, then check the Soot accumulation %.
- If the Soot accumulation ratio is below 135%, clear all DTC and perform Forced Regeneration with SSM III.
- At the completion of the forced regeneration, Re-connect the two pipes to the DPF pressure difference sensor, start the engine and idle for 1 minute, cycle the engine speed between idle and 2500rpm repeatedly for 1 minute, then re-check the Soot accumulation ratio %.
- If the Soot accumulation ratio % is still above 50%, carry out a second forced regeneration with SSM III to achieve a true low soot accumulation ratio. (NOTE: Please ensure that rear muffler temperature is not excessive and causes damage to the rear bumper cover.)
- If this procedure is not successful, please advise Technical via FPRS report.

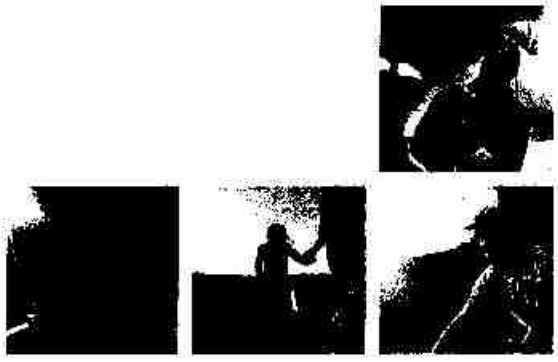
Diagnosis Flow Chart



Kind regards,

J.R. Funston

Jim Funston
National Technical Advisor



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