

Emissions Control and Diagnosis

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Introduction;

The aims of this report are to review the various measures implemented by manufacturers to reduce emissions produced by vehicles. Given the recent and growing issue of global warming and increasing air pollution, many measures have been taken in the vehicle industry to ensure a reduction of emissions to ensure less pollution is created and fewer harmful gasses are expelled by a vehicle. The systems that will be discussed are, catalytic converters, evaporative, exhaust gas recirculation, secondary air injection, positive crank case ventilation valve, the air / fuel ratio and the restrictions implemented by the Euro 6 agreement. As well as discussing the basic functions of these systems, any tests carried that can be completed to determine if there are any faults within the systems will be discussed.

Catalytic converter;

The simple function of a catalytic converter is to convert nitrogen oxide, carbon monoxide and hydrocarbons into nitrogen, oxygen, carbon dioxide and water. There are two primary types of catalytic converter, ones with a metal monolith and the other with a ceramic monolith. Within the monolith there are numerous channels running parallel to each other, each coated in catalytic coating. The number of channels varies from 400 to 1,200. (Bosch, 2007) The metal monolith channels are finely corrugated. Because of this there is an incredibly low resistance therefore allows for ease of flow for exhaust gasses. A ceramic monolith is made of cordierite, a lightweight material that operates well at high temperatures and poorly conducts heat therefore improves efficiency by retaining this heat. (Venables, n.d.) Due to the difference in thermal expansion rates between the steel of the exhaust and the ceramic, it must be carefully mounted, and a flexible protective mat is placed between the both. To obtain maximum efficiency of the catalytic converter, it must be placed as close to the engine as possible. This is to ensure it reaches operating temperature as quickly as possible. To monitor a catalytic converter, one or two probes can be placed in the exhaust system, one prior the catalytic converter and one after. The probe measures the amount of oxygen in the exhaust and compares it to a pre-set that is written into the ECU. If the system recognises that the oxygen content to be within the tolerance, then it will carry on operating in the same manner. If the system monitors that there is a change in the oxygen content that breaches the threshold then the system will lean / enrichen the mixture to combat this. (patents, n.d.) If a catalytic converter has failed or is performing poorly, there are procedures that can be undertaken to investigate. First of all, would be to probe the vehicles ECU if it shows a fault regarding the oxygen sensor. A fault code could indicate that the sensor is failing to balance the mixture within the tolerance. Another symptom would be a higher output of emissions, this can be tested with an emission probe in the exhaust tip and then testing the vehicle at various loads and speeds. On newer vehicles that conform to recent euro emission standards, probing the pre and post oxygen sensor would also indicate if the catalytic converter has failed or is weakened. By comparing the signal waveforms produced by the oxygen sensor it would be clear if the catalytic converter has failed or if it is performing below standard if the wave forms are either the same or show very little difference.

EVAP;

An EVAP (Evaporative emission control system) system works by venting the gasses created in the fuel system into the intake manifold to be burnt during combustion and prevents them being vented to atmosphere. The vapours are vented and stored in a charcoal canister until they are purged into the intake system. Approximately 20% of hydrocarbons produced by a vehicle are evaporative, therefore implementing a system such as this is highly beneficial and crucial. (Toyota, n.d.) The EVAP system will only engage under certain conditions, if the engine were to be at idle speed then the EVAP system will never engage. Normally the charcoal canister will purge when the throttle has been opened beyond a certain point. Once the throttle has been opened past this point a purge port is engaged allowing the vapours to flow from the high-pressure area of the canister to the low-pressure area of the intake valve created by natural vacuum. The purge occurs during phases of driving where the engine will be experiencing a leaner burn, this is to avoid over richness and poor driveability, over richness would also cause an increase of emissions due to a certain amount of unburnt fuel flowing through the exhaust and to atmosphere.

EGR;

Exhaust gas recirculation is an emission control measure that aims to reduce the amount of NO_x produced. By recirculating exhaust gasses back into the combustion chamber, it is possible to reduce NO_x levels without hindering engine performance. Approximately 6-10% of exhaust gasses are recirculated but since the gasses do not interfere with combustion, as they are inert, the results are lower combustion temperatures. This aids in combating detonation which can occur if the cylinder reaches extremely high temperatures. Higher combustion temperatures result in a significant increase in the production of NO_x therefore the cooling effect of the EGR greatly reduces this. (Bosch, Automotive handbook, 2007). The EGR functions through a vacuum opening and closing a valve within the system, a temperature control cut-off is implemented to prevent the EGR engaging whilst the engine is still below a certain temperature. Whilst the EGR is engaged the pressure in the intake manifold increases, because of this fuel consumption is decreased. EGR cannot be implemented during idle or if the engine is cold. If EGR were to be implemented at idle the engine would not function properly as there would be an insufficient amount of air entering the cylinder, therefore not allowing enough air to create a clean burn. It also cannot be engaged whilst the engine is cold as EGR reduces core cylinder temperatures meaning it would slow the warm up phase considerably and have a knock-on effect on other components such as the catalytic converter. (Khair)

SAIR;

The SAIR (Secondary air injection) works by utilising an air pump, either belt driven by the engine, or more commonly electric air pump. The air pump uses a one-way valve situated after the pump that is controlled by a solenoid to decide which path the air is sent down. If the engine is cold and in warm up phase, the air is directed into the exhaust manifold to aid with heating the catalytic converter to the optimum operating temperature. Once the engine is warm the air is pumped directly into the catalytic converter to ensure it remains at operating temperature to ensure consistent efficiency. By doing this it aids the catalytic converter oxidise hydrocarbons and carbon monoxide. If the ECU recognises an increased vacuum above idle, a second valve is opened, and the air is diverted to the air filter to avoid backfire. (Bosch, Automotive handbook, 2007) (Hilier, 2012)

PCV;

The PCV (Positive crank case ventilation) system is crucial for circulating oil vapours into the intake to be burnt during the combustion process. Older systems that did not implement such a system would vent to atmosphere, this led to visual pollutants such as smog. If the engine speed is low, when vacuum speed is high, the valve restricts air flow and reduces the risk of oil being incorrectly mixed with the fuel mixture. This is typically seen during the idle phase or under normal cruising conditions. If the engine experiences high load and high speed, the valve is opened fully to allow maximum air flow for optimum efficiency of the system. The valve will automatically shut off if the engine backfires as not to cause detonation within the crankcase. Maintaining the PCV is essential due to this factor as if it were to fail it could cause serious issues. If it thought that the PCV has failed, there are tests that can be conducted to determine this. Removal of the oil cap and placing a small piece of card across it will indicate if there is vacuum in the system, if it is held in place by the vacuum then the PCV is still functional. On newer vehicles there will be monitoring systems upon the PCV such as a pressure sensor which will indicate a fault if the pressure falls below a pre-set in the ECU. (Kwas, 2015)

Air / Fuel ratio;

The air / fuel mixture relates to the amount of fuel and air the engine is receiving during combustion. The ideal mixture is 14.1, if it were to run lean then there would be more air in the system than fuel, if the system were to run rich the fuel content would be higher. The air / fuel ratio can be very delicate and can have large impacts if made too lean or too rich. If the mixture is changed to a mixture of 1.1 which is slightly lean, NO_x outputs peak, whereas if the mixture is set at 0.9 which is slightly rich, the temperature increases but oxygen content is low therefore causing carbon monoxide levels rise. If a vehicle were to run richer than it should then fuel consumption would be increased and performance of the engine would be decreased, Carbon monoxide and hydrocarbons are vastly increased although NO_x is less due to the lower temperature. If the vehicle were to run lean however then NO_x would greatly be increased due to the higher temperature which can also put excess strain and wear of engine components and cause premature engine failure. Carbon monoxide is decreased whilst running lean however hydrocarbons increase. There are systems in place to monitor the change in air / fuel ratio such as lambda which will alter the mixture to conform with the pre-set of the ECU. (Nick, n.d.)

Euro 6;

The current Euro emissions standard, which was implemented in 2015, the main changes implemented compared to previous years was a reduction in NO_x and HC. The limit for carbon monoxide did not change for light petrol and diesel vehicles, which still remains at 0.50gm/km for diesels and 0.10gm/km for petrol engines. However, targets for NO_x and HC levels were greatly increased. The target for Euro 5 was 0.180gm/km of NO_x and 0.230gm/km of HC in diesels, for euro 6 however the limit for NO_x was 0.80gm/km and HC were 0.170gm/km. Petrol engines did not receive any change during the transition from euro 5 to 6. Given the technology of petrol engines in regards to emissions have not evolved greatly, it is clear to see why emission reduction development has been more prominent in diesel engines. Given the new legislation given there have been development in systems such as EGR, DPF and the addition of ad-blue, with the main focus of reducing the effects of NO_x.

Euro 6 emissions standards (petrol)

CO: 1.0g/km

THC: 0.10g/km

NMHC: 0.068g/km

NOx: 0.06g/km

PM: 0.005g/km (direct injection only)

PN [# /km]: 6.0×10^{11} /km (direct injection only)

Euro 6 emissions standards (diesel)

CO: 0.50g/km

HC + NOx: 0.17g/km

NOx: 0.08g/km

PM: 0.005g/km

PN [# /km]: 6.0×10^{11} /km

(RAC, n.d.)

Future of Euro emission standards (Euro 7)

For the next phase of the euro emissions standard it would seem fair to assume that the aim for NOx and HC reduction to continue. Again, the main focus being on diesels, since the aims of euro were incredibly harsh, given that the NOx limit was more than halved. It seems that the legislation is moving towards making diesels on par with petrol engines in respect to emissions. With that the hope that manufacturers would respond to such changes by implementing new systems to tackle emissions, whether it be in cleaning exhaust gases or creating engines that are less pollutant. Along with this the hope that the legislation will make the addition of sensors mandatory for all new systems that are implemented to alert the operator of any faults within the system, so they may be replaced immediately to ensure that the emission standard can be met continuously. An example of this has been seen in previous euro systems, in 2004 it became mandatory for all vehicles to be equipped with pre and post catalytic converter lambda sensors to aid the accuracy of the system and for ease of diagnosis in case of a fault.

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