

European Emissions Standards

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Abstract

This paper highlights the problems that is associated with motor vehicle pollution by gaining an understanding of the problem with a high polluting vehicle and the steps that can be made to reduce the pollution. The goal of this paper is to conducts test on two engine test rigs which conforms to certain emission standards and to identify the operation of the emission control systems to gain an understanding of how the emissions is monitored, controlled and rectified.

European standards govern the minimum output of pollutants that's exhausted from an engine so by conducting primary and secondary research, an educated guess can be made to predict future emission regulations.

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1. Introduction

Air pollution is a recent problem that's been around for years. The accessibility to personal vehicles means that there are billions of vehicles on the road causing and contributing to pollution. Even though the pollutions isn't solely from motor vehicles it is a contributor. For example 75% of carbon monoxide in the air is produced by cars in the United States. By reducing the amount of emissions that exists the cars we and control a vast majority of the pollutants in the air. The Euro Emissions standard dose jut that by ensure that can manufacturers comply with strict emission output standards.

By conducting tests on test engines of euro 3 and 4 standards to gain an understanding of the measures taken to conform to the standards and create a low polluting car. By utilizing various equipment, test are conducted to identify the emission output and to identify emission control system operation under different scenarios.

European standards can be researched to identify the past Euro revision standards and the present. Using the information an educated guess can be made to about the unknown euro 7 standard.

2. Emission control systems

- **Catalytic converter**

Catalytic converter or “CAT” for short takes the exhaust gasses from the engine and converts toxic and polluting gasses to less harmful gasses. This process is accomplished by using rare earth metals like platinum, palladium and rhodium which don’t degrade. This means that they are catalyst to allow a chemical reaction to take place in the exhaust. A honeycomb construction is utilised in the converter and is composed of mainly ceramics. The ceramic honeycomb allows the gasses to flow through while creating a large surface area so the rare metals can be incorporated to allow maximum conversion of the exhaust gasses. For the catalytic converter to perform correctly a temperature of 426°C needs to be achieved so that the system can perform in its optimum range allowing more complete gas conversion. To achieve the correct operating temperatures, the catalytic converter is placed closest to the exhaust manifold which allows the system work in the specified temperature tolerance.

Catalytic converters incorporate oxygen sensors or also known as lambda sensors. These sensors monitor the concentration of oxygen in the exhaust. This is to allow the air /fuel mixture to be adjusted accordingly so that the catalytic converter can work at its optimum and not be damaged. The oxygen sensor was initially placed before the catalytic converter but on the early systems but was placed on before and after the converter. This second oxygen sensor is to monitor the operation of the catalytic converter to ensure the system works. If the sensor detects a difference in reading then the system is working but if the sensors are outputting the same reading means that the catalytic converter isn’t working correctly. The ECU monitors these readings, and detects the changes but will only monitor under certain conditions. These conditions are as follows: intake temperature over 0°C, engine temperature is over 18°C, mass of air is between 15 and 32 g/sec, engine load is under 64%, engine speed is lower than 4000rpm and these conditions operate for longer than 4 minutes. If these conditions are not met, then the ECU will not monitor the system. If the operation is monitored but then catalytic converter performance is hampered, then the ECU will output a warning light to alert the driver of a problem. Once the vehicle is brought in for a service, a technician can utilise a universal scope to read the outputs from the oxygen sensors to confirm the problem by identifying if there is a difference in scope patterns to confirm if there is any problems. (Sideris, 1998) (GmbH, 2007)

- **EVAP**

An EVAP or Evaporative Emission Control System is used to ensure that gasoline vapours don’t escape into the atmosphere from the fuel tank and the fuel system. Fuel vapours contain various hydrocarbons and other gasses. If the gasses are released into the atmosphere a chemical reaction takes place when exposed to sunlight which creates smog. A charcoal canister is used to trap escaping vapours which is connected to the fuel tank and from the fuel system. The charcoal canister then vents to the intake of the engine to be

burned in the combustion process. In addition to the charcoal canister is the air tight fuel cap and the purge valve. The fuel cap is air tight so that no gasses leak into the atmosphere otherwise it would make the system redundant. The fuel cap dose has a pressure vacuum valve to prevent vacuum lock so that the system continues to operate. The purge valve which composes of a spring loaded diaphragm then regulates the amount of vapour that enters the intake when there is manifold vacuum. On a modern system the ECU controls the solenoid purge valve. The normally closed purge valve is pulsated accordingly and the fumes is sucked by the intake of the engine. The system also incorporates a normally open vent valve to ensure air enters the tank so that there isn't a large vacuum in the tank. EVAP system flow needs to be monitored to detect if the system is working. A fuel tank pressure sensor is also used to detect if the system holds a pressure which allows the system to detect if there is a leak. (Agarwal et al., n.d.)

- **EGR**

An EGR or "Engine Gas Recirculation" uses the exhaust gasses and is added into the intake of the engine. The main purpose of the EGR is to reduce NOx emissions in the combustion process. NOx occurs at high temperatures typically at around 1370°C. The purpose of EGR is to reduce the cylinder temperatures so that NOx formation is reduced. When EGR is off the combustion burn can reach around 2500°C which is ideal for NOx formation. With the high pressures involved, detonation is more likely. When the EGR system is activates the air/fuel ratio changes so that the cylinder combustion temperatures are reduced. This is due to the fact that the spend exhaust gasses is inert so can be burnt. It also allows for grated ignition advance so the engine efficiency can be increased. NOx is still present but in low quantities can be converted in the catalytic converter. EGR is also sued under certain conditions. These conditions are as follows: cold engine, Idle and wide open throttle. (Probst, 1991)

- **SAIR**

SAIR or "Secondary Air Injection" is an air pump which is directed in the exhaust system to help the catalectic converter to further convert the toxic gasses into less harmful gasses. The pump is ether electric or is manually driven by a pulley on the front of the engine. The system also incorporated a solenoid valve to regulate the amount of air that enters the exhaust. Before the catalytic converter there are many different gasses but the main gasses that would benefit from air injection is HC and CO. When additional air is introduced the HC and CO gasses oxidises to into H₂O and CO₂ after the catalectic converter. This system is controlled by the ECU which allows the system to activate only under certain engine conditions. When the engine is cold and in its warm-up phase, more exhaust gasses are exhausted. The air is injected into the exhaust manifold to help oxidise these gasses so that HC and CO is reduced. When the engine has warmed up the air is directly injected into the Catalytic converter for optimum conversion of gases. When the engine is in overrun the system redirects the air into the intake to avoid backfire. (Probst, 1991) (Hillier, Hillier and Smith, 2012)

- **PCV**

The PCV valve or “Positive Crank Case ventilation” ventilates the crank case oil vapours into the intake to be burnt by the combustion process. The early engine exhaust the vapours directly into the atmosphere which reacts with the sunlight to create smog. The PCV system incorporates a spring loaded plunger that controls the flow rate into the intake. The flow rate depends on different conditions. When there is a high amount of manifold vacuum when the engine is at idle or cruising, the valve restricts the flow. Under high load the valve opens to allow for maximum air flow. If the engine backfires then the valve closes to prevent crank case explosions. All of these conditions ensures that the engine can ventilate the crank while reducing the controlling and regulating the toxic hydrocarbons. Most valves are calibrated for specific engines due to the fact that different engines have different pressures so to ensure correct operation a matched valve is selected.

The PCV valve is essential to be maintained due to the fact that the engine takes 30% of air from the PCV. To ensure correct operation of the valve, different procedures can be adopted and applied. There are two main methods to check if the PCV valve is working. The first, method is to leave the engine idling and with the oil cap off, and measure the vacuum using a vacuum gauge. The second test is similar except to check the vacuum through the dipstick hole. On later systems a there is a pressure sensor in the PCV system to makes it easier to check if the system if functioning correctly. (Ferrell, 2019)

- **Air/Fuel Ratio**

Air fuel ratio refers the amount of air and fuel enters the combustion chamber. The ratio typically has names to describe the condition of the air fuel ratio. When an engine is rich, there is more fuel compared to air. If the engine is lean, the mixture has more air compared to fuel. The ideal fuel ratio is 14:1 which is ideal for majority of engine but varies due to different conditions.

These air/fuel ratios effect the emissions output dramatically as well as performance. Many different sensors like lambda take in information from the engine and varies the air/ fuel ratio depending on the state of the fuel. If the system runs and rich mixture then the performance of the engine is dramatically reduces as well as the efficiency because it used more fuel but may produce more power and also burns at a cooler temperature. Because of the increased fuel burn, CO and HC are at its highest but NOx is less likely to form due to the lower temperatures. Lean burning vehicles are more efficient because it used less fuel but has the disadvantage to burn at higher temperatures which can increase the formation of NOx gasses but the formation of CO and HC is reduced. The ideal AFR ratio of 14:1 has the combination of low HC but has an average amount of CO and NOx where the crossing points meets. (Miller, Vandome and McBrewster, 2009) (Hillier, Hillier and Smith, 2012)

3. Past Euro Standards

Euro standard create a norm for emission standard for new vehicles sold in the European Union. These stringent standard ensure that manufacturers conform to a set standard to reduce the emission that's exhausted through the exhaust. There has been many revisions to the euro standards. The euro standards are identified by revision number i.e. euro1, euro 2, euro3 etc. The euro stands also apply to larger vehicles but conform to their own emissions output limits. Diesels also have limitation to requiring it's ow limitation of pollution out of the exhaust. The euro standard requirements for passenger vehicle are listed below:

Euro 1: Implemented in 1992 and requires manufacturers to fit catalytic converters as standard and for all gasoline fuel to switch from leaded fuel to un-leaded. Only HC and NOx was tested due to the lack knowledge about the effects of CO₂. Diesel particulate matter was also limited in the case of diesels.

Euro 1 emissions standards (petrol) CO: 2.72g/km HC + NOx: 0.97g/km

Euro 1 emissions standards (diesel) CO: 2.72g/km HC + NOx: 0.97g/km PM: 0.14g/km

Euro 2: Implemented 1997 which introduced a limit for CO and reducing the limit of HC and NOx further.

Euro 2 emissions standards (petrol) CO: 2.2g/km HC + NOx: 0.5g/km

Euro 2 emissions standards (diesel) CO: 1.0g/km HC + NOx: 0.7g/km PM: 0.08g/km

Euro 3: Implemented 2001 separates HC and NOx limits of petrol and diesel engines. Also introducing separate NOx emissions limits for diesel. The warm up phase removed from test procedure.

Euro 3 emissions standards (petrol) CO: 2.3g/km THC: 0.20g/km NOx: 0.15g/km

Euro 3 emissions standards (diesel) CO: 0.66g/km HC + NOx: 0.56g/km NOx: 0.50g/km PM: 0.05g/km

Euro 4: Introduced 2006 reducing the emission output limits.

Euro 4 emissions standards (petrol) CO: 1.0g/km THC: 0.10g/km NOx: 0.08g/km

Euro 4 emissions standards (diesel) CO: 0.50g/km HC + NOx: 0.30g/km NOx: 0.25g/km PM: 0.025g/km

Euro 5: Implemented 2011 making DPF (Diesel Particulate Filters) to be fitted as a requirement and to capture 99% of all particulate matter. Lower emission output limits throughout. Euro 5 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)

Euro 5 emissions standards (diesel) CO: 0.50g/km HC + NOx: 0.23g/km NOx: 0.18g/km PM: 0.005g/km PN [#/km]: 6.0×10^{11} /km

(Rac.co.uk, 2019)

To conform to the euro emission standards, car manufacturers develop systems to conform to the set emission limitations. These systems are listed and operation explained in the above Emission control systems.

(Rac.co.uk, 2019)

4, Present Euro Standard

The current euro standard is euro six which was introduced in 2015. Due to findings in the health implications of vehicle emissions it was found that NOx is one of the causes to respiratory problems. Due to this fact, NOx emissions is reduced from 0.18g/km in Euro 5 to 0.08g/km. (Zeben, 2014) To meet the presented standards, vehicle manufacturers are introducing selective catalytic reduction (SCR) which injects a liquid reductant agent through the catalytic converter of a diesel vehicle. This causes a chemical reaction in which converts the NOx into water and nitrogen which is exhausted through the exhaust pipe. The most common and most popular version of liquid reductant agent is addblue. (Probst, 1991). Without this system, meeting the emission requirements is difficult or even impossible. To further decrease the NOx, EGR is used but under a more controllable state due to the amount of sensors that monitor the engine which is in accordance to load and speed. By reducing NOx can have an increased benefit on the public and environment not just to satisfy the legislation. This ensures that the air remains clear and pollution free to reduce the health risks associated. This is why diesels are under more scrutiny because diesels create more NOx and PT compared to petrol engines. (Zeben, 2014)

Below is Euro 6 standards of petrol and diesel engines.

Euro 6 emissions standards (petrol)

CO: 1.0g/km

THC: 0.10g/km

NMHC: 0.068g/km

NOx: 0.06g/km

Euro 6 emissions standards (diesel)

CO: 0.50g/km

HC + NOx: 0.17g/km

NOx: 0.08g/km

PM: 0.005g/km (Rac.co.uk, 2019)

5. Future Euro Standard

In the future euro emission standard could have many different changes to further decrease the emission output. Based on the previous euro standards, an educated guess can be made by identifying a pattern and applying it to the relevant emission. In previous euro revisions, NOx is the main target to identify and reduce. Between euro 5 and 6, the NOx emissions were decreased by 62%. The technology isn't available to reduce NOx by a further 62% but there is a possibility to match the NOx output of the gasoline engines which is 0.06g/km. If HC + NOx was also compared in the euro 5 and 6, it had a reduction of 26%. Applying this theory to the same gas, Euro 7 will have HC + NOx at 127g/kg. All other gasses would stay the same for the diesels. For the gasoline engines which haven't changed the regulation specification since euro 4. There is a possibility of the gasoline engine reducing the CO from 1.0g/km to possibly 0.7g/km. This is a decrease of 30% which is quite reasonable. To also further reduce the amount of NOx emissions, lean burn can be introduced but is only advisable if the engine doesn't overheat from the increased temperatures.

In euro 4 it's mandatory for the catalytic converter to have a pre and post oxygen sensor. This is to detect the operation of the system and know if the catalytic converter is fully operational. Quite possibly euro 7 implements the same system of monitoring emission control systems before and after operation. This is to ensure all systems are operational after the sale of the vehicle to ensure that the vehicle conforms to the euro standard for the life span of the vehicle.

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