Association for Emissions Control by Catalyst AISBL

AECC INPUT ON EURO 6 MAINSTREAM DIESEL VEHICLES AND TECHNICAL IMPROVEMENT

AECC* welcomes the adoption by EU Member States on 19 May 2015 of the first package on a Real-Driving Emissions (RDE) test procedure. This sets the basis for enhancing the Euro 6 Regulation (EC) 715/2007 on emissions from passenger cars and light-duty vehicles. The industry that AECC represents sees RDE as vital to ensure that Euro 6 delivers the air quality benefit needed by EU Member States, local authorities and citizens.

In that context, AECC would like to support the European Commission's work to establish a first step NOx Conformity Factor that will reflect Euro 6 mainstream technology and will take into account technical improvements that can be expected for models to be put on the market in 2017/2018.

AECC members develop, produce, and sell Diesel NOx emissions control technologies such as Selective Catalytic Reduction (SCR) and Lean NOx Traps (LNT), both are used in aftertreatment systems in Euro 6b Diesel vehicles together with engine measures such as efficient advanced combustion modes in combination with Exhaust Gas Recirculation (EGR) which limits engine-out NOx.

The two **mainstream aftertreatment technologies** (SCR and LNT) are about equally distributed on existing applications. Both technologies allow Diesel engine developers to take advantage of the trade-off between NOx, PM and CO_2 emissions and calibrate the engine in an optimal area of fuel efficiency, rather than to reduce NOx by engine measures alone. A combination of these technologies is possible to ensure a proper control of NOx and CO_2 emissions in all driving modes including those outside of the NEDC or WLTC regulatory test cycles.

Selective Catalytic Reduction (SCR) was originally developed and used to reduce NOx emissions from coal, oil and gas-fired power stations, marine vessels and stationary Diesel engines. SCR technology permits the NOx reduction reaction to take place in an oxidizing atmosphere. It is called "selective" because the catalytic reduction of NOx with ammonia (NH_3) as a reductant occurs preferentially to the oxidation of NH_3 with oxygen.

Today SCR technology is fitted to most new heavy-duty (i.e. truck and bus) Diesel engines in Europe. A growing number of Diesel light-duty vehicles and passenger cars are also equipped with SCR systems. Once the exhaust system is warm enough, SCR provides high levels of NOx reduction, when appropriate amounts of ammonia reductant are injected into the exhaust stream. Ammonia is provided to the SCR catalyst by in-situ decomposition of a colourless and odourless solution of urea in water (AdBlue®), carefully metered from a separate tank and sprayed into the exhaust system. The consumption of AdBlue® for a Euro 6b vehicle strongly depends on the car manufacturer product strategy, vehicle application, driving style, load, and road conditions and the urea tank needs to be topped up periodically.

Several types of catalyst can be used in SCR systems; the choice of which is determined by the temperature of the exhaust environment. Current passenger car SCR systems use copper-zeolite-based catalyst as these have the best low temperature performance; iron-zeolite-based

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catalysts have the best high temperature performance. Vanadia may also be used where tolerance to sulfur is required, provided temperatures are below 600°C.

New systems developments that combine the SCR catalyst into the Diesel Particulate Filter (SDPF), sometimes in association with a downstream SCR catalyst, are reaching vehicle application and give significant improvement in the NOx conversion efficiency compared to separate components. Development of SCR technology is very dynamic and improvements are being made in low temperature performance, urea delivery systems, system design, exhaust flow mixing devices, urea dosing strategy, and providing alternatives to liquid urea.

Lean NOx Traps (LNT) adsorb and store NOx under lean conditions. The function of the NOx storage element is fulfilled by materials that are able to form sufficiently stable nitrates within the temperature range determined by lean operating engine points. Thus especially alkaline, alkaline earth and to a certain extent also rare-earth compounds can be used to store NOx over a broad temperature range.

When this storage media reaches its capacity, it must be regenerated. This is accomplished in a NOx regeneration step. In such a regeneration, the stored NOx is released by creating a rich atmosphere. The rich running portion is of very short duration and can be accomplished in a number of ways, but usually includes some combination of intake air throttling, EGR, late ignition timing, fuel injection in upstream LNT position, and post-combustion fuel injection. The released NOx is quickly reduced to N_2 by reaction with CO on a precious metal that is incorporated into this unique single catalyst architecture.

As alkaline and alkaline earth compounds have a strong affinity for sulfation a regular deSOx strategy is implemented in all LNT applications to minimize this effect.

Besides the deNOx functionality of an LNT, excellent low temperature conversions of CO and HC are beneficial to comply with Euro 6 limits. LNT can also be combined with the Diesel Particulate Filter or the NOx storage function can be combined with the DOC to simplify the global exhaust line integration. As with SCR, LNT technology is developing at high speed with improvements in the operation window, stability, and low and high temperature performance.

Synergies are possible with both deNOx aftertreatment technologies. SCR and LNT can be combined with either of them used in “passive mode” which limits the urea or the fuel consumption while still providing improvement in global NOx conversion efficiency.

AECC recently ran **two test programmes** on vehicles equipped with SCR where on-road emissions where measured, first on a development car whose engine and aftertreatment systems were recalibrated to improve real-world performance, and second on a commercially available Euro 6b vehicle equipped with advanced emissions control technology.

The **emissions control system of a Diesel demonstrator vehicle was recalibrated** for AECC by an independent institute [1]. Baseline NOx emissions in real driving, were 3.4 times higher than the Euro 6 type-approval limit. Recalibration of the high-pressure EGR and of the urea injection into the underfloor SCR-coated Diesel Particulate Filter (SDPF) was performed. This approach reduced average real-driving NOx emissions on three RDE tests down to an average of 111 mg/km **(1.10 to 1.57 times the Euro 6 limit in three tests)** whilst continuing to meet Euro 6 Diesel limits for other pollutants. The NOx conversion improvement achieved included some comprehensive recalibration and system changes that will take time to apply across the fleet.

AECC then commissioned a second test programme [2] at Ricardo, UK. This time, a **commercially available 2-litre Euro 6b Diesel car** was rented to evaluate the emissions performance of a market vehicle using advanced emissions control. The car used high- and low-pressure EGR to reduce engine-out NOx levels. The aftertreatment system installed to control tailpipe NOx emissions included a close-coupled Diesel Oxidation Catalyst (DOC) immediately followed by an SDPF. The Euro 6b Diesel rental car in fresh state showed NOx emissions 1.44 times the Euro 6 limit when tested according to the agreed RDE procedure and boundary conditions, including PEMS data post-processing with EMROAD. These test results should not be considered as representative for the average mainstream Euro 6b Diesel vehicles as the vehicle was carefully selected based on good performance during RDE testing from the limited choice available in the Emissions Analytics database. It does however demonstrate the level of best-available technology currently available.

So far AECC has tested a limited number of vehicles against the new RDE test procedure. Both test series were conducted on cars that had limited mileage so cannot provide information on emission system durability. Also, the small/medium car segment may face more challenges in installing additional systems cost effectively than the larger vehicles tested by AECC and, to achieve low real-driving emissions, manufacturers will have to adapt their global product strategy to fully optimise a range of engine and vehicle combinations.

The industry foresees **further development of catalytic components as well as combinations of them in high performing systems for NOx abatement** under real-driving conditions while maintaining the fuel efficiency of Diesel engines. Historically, new best-available technology has been substantially optimised in cost as application experience increases. Thereby a stepwise approach on NOx Conformity Factors allows best-available technologies to be used and to spread across the fleet over time.

Further technical information and literature references can be found in the AECC summary “Emissions Control Technologies to meet current and future European vehicle emissions legislation” at www.aecc.eu/content/pdf/Emissions%20Control%20Technologies%20to%20meet%20current%20and%20future%20European%20vehicle%20emissions%20legislation.pdf.

References:

[1] “Potential for Euro 6 Passenger Cars with SCR to meet RDE Requirements”, 36th International Vienna Motor Symposium, May 2015, www.aecc.eu/content/pdf/150507%20FEV-AECC%20paper%20Potential%20for%20Euro%206%20Passenger%20Cars%20with%20SCR%20to%20meet%20RDE.pdf.

[2] “New results from a 2015 PEMS testing campaign on a Diesel Euro 6b vehicle”, 11th Integer Emissions Summit, June 2015, www.aecc.eu/content/pdf/150618%20Integer%20conf%20AECC%20RDE%20Program%20presentation%20final.pdf.

** AECC is an international non-profit scientific association of European companies engaged in the development, production and testing of catalyst and filter based technologies for vehicle and engine emissions control. This includes the research, development, testing and manufacture of autocatalysts, substrates and speciality materials incorporated into the catalytic converter and filter and catalyst-based technologies to control engine emissions. Members' technology is incorporated in the exhaust emission control systems on new cars, commercial vehicles, buses, non-road mobile machinery and motorcycles in Europe. More information on AECC can be found at www.aecc.eu. Information on emissions control retrofit for existing heavy-duty vehicles and non-road machinery can also be found at www.dieselretrofit.eu.*

AECC's members are: BASF Catalysts Germany GmbH, Germany; Ibiden Europe B.V. Stuttgart Branch, Germany; Johnson Matthey PLC, United Kingdom; NGK Europe GmbH, Germany; Solvay, France; and Umicore AG & Co. KG, Germany.

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