AECC Response to Public Consultation on Future Euro VI Emissions Limits for Heavy-duty Vehicles

AECC is pleased to provide input to the Commission's public consultation on Future Euro VI Emissions Limits for Heavy-duty Vehicles.

AECC recognises that the European automotive industry and their suppliers are crucial participants in the drive to improve air quality and minimise related health effects to the benefit of European society as a whole. AECC understands that the motor industry needs a clear long-term view of future requirements and that the industry envisages benefits from the worldwide harmonisation of requirements for Heavy-duty engines. Challenging legislation will therefore enable the industry to apply available and appropriate emissions control technologies world-wide.

Technologies Available

Effective emissions treatment technologies are available for fitment to Heavy-duty engines. For diesel engines, diesel oxidation catalysts are already widely used to reduce CO, HC and the organic fractions of particulate matter. Many engine manufacturers have also chosen to use urea-Selective Catalytic Reduction (SCR) systems to meet Euro IV, Euro V and EEV emissions requirements. The manufacturers say that use of such systems to control NOx allows engine optimisation to meet the particulate emissions requirements whilst providing a fuel economy benefit. Highly efficient wall-flow particulate filters are also widely used in European Light-duty vehicles to control particulate emissions and are now being fitted to many American Heavy-duty engines to meet the US 2007 emissions requirements. A large number of retrofit installations have also been made in Europe, especially for city bus operations. Partial flow filters are being used to reduce particulate emissions of modern engines without active regeneration where engine manufactures have chosen to limit NOx by engine measures alone, as well as in retrofit applications.

For Heavy-duty spark-ignition engines operated under stoichiometric conditions, three-way catalysts (TWC) to control CO, HC and NOx are an accepted and reliable technology. For lean-burn spark-ignition engines oxidation catalysts are normally used to reduce CO and HC, and technologies such as NOx adsorbers and SCR are available for additional NOx control.

Commission Scenarios

The consultation document presents four scenarios of possible air pollutant emissions limits for CI and PI engines. Data from AECC's recent Heavy-duty Euro VI test programme demonstrated that with the appropriate technologies, even the most stringent of the consultation scenarios for CI engines was achievable in a single step with emissions treatment systems that are already available. With a wall-flow filter, filtration efficiencies of 99.8% for particulate mass and 99.9% for particle number were achieved in this programme. NOx conversion efficiencies of over 85% were achieved using SCR in two AECC programmes using Heavy-duty engines with significantly different engine-out emissions levels.

The consultation scenarios show not only possible limits for pollutant emissions but also an estimate of the additional CO_2 emissions anticipated as a result of achieving these levels of control of air pollutants that are damaging to human health and the environment. The CO_2 penalty in the ETC test is associated with the system back-pressure and the need for regeneration of the particulate filter. Hence it is dependant on the design of the system and the engine-out emissions of particulate matter. For the AECC test programme, the difference between the fuel consumption of the complete system and the original engine system, including OE particulate filter, was 1.6%. With regards to regeneration, it is important to recognise that only part of this CO_2 penalty results from additional fuel consumed during regeneration, as the burning of accumulated carbon (soot) results in conversion of that accumulated carbon to CO_2. Data from the AECC Heavy-duty Euro VI test programme indicates that engine-out CO_2 emissions (which relate to fuel consumption) over the complete fill-and-regenerate cycle were within 1% of the emissions without regeneration despite the more frequent regenerations which would be needed as a result of this engine's comparatively high engine-out soot emissions.

Engine technology has developed and continues to develop to enable improved engine-out emissions and fuel economy. The rapid development of large light-duty vehicles capable of

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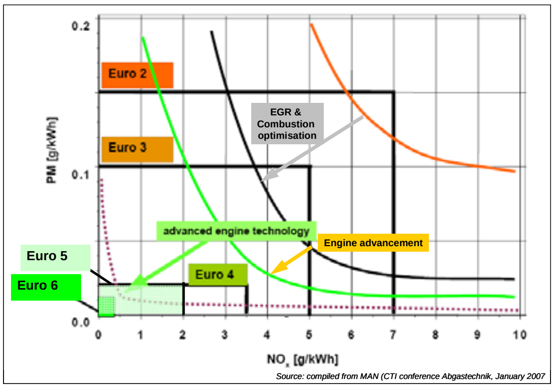
meeting US Tier 2 Bin 5 emissions requirements, including one without NOx aftertreatment[1] indicates the rapid pace of development. At least one Heavy-duty engine manufacturer has already announced a model that will meet the Euro V standard without aftertreatment. Any estimate of fuel consumption penalties as a result of measures to reduce emissions may therefore overestimate the effects on CO_2.

AECC Test Progammes

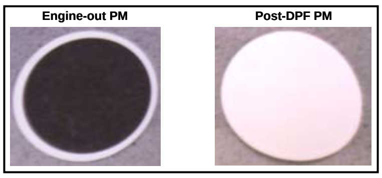
The AECC Heavy-duty Euro VI test programme completed in 2007 was conducted at the laboratories of an established European engine consultancy using a commercially-available engine with low engine-out NOx emissions and fitted by AECC with an integrated emission control system. This system comprised a NOx sensor, an oxidation catalyst, a catalysed wall-flow particulate filter, a urea dosing system capable of providing appropriate dosing levels, and a urea-SCR unit with ammonia-slip catalyst. The programme included measurement of emissions of regulated emissions and of particulate mass and number to the PMP protocol being developed by the UN/ECE working groups. Our comments also include some reference to the previous test programme (AECC Heavy-duty Euro V Test Programme), completed in 2002 and conducted at the same laboratory. Using a Euro III engine with an emissions control system provided by AECC, this achieved levels half those of the Euro V requirements after severe ageing, equivalent to 250000km of real-world driving. This system also used a particulate filter and urea-SCR system.

CI Engines

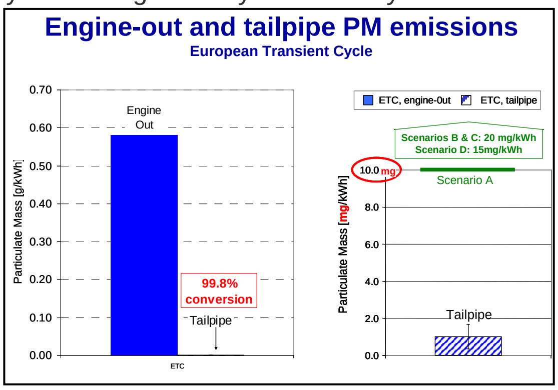
The emissions levels which can be achieved depend upon both the engine-out emissions and the performance of the emissions control system. For the engine-out emissions there is a well-known trade-off between PM and NOx. This trade-off is not, however, a constant relationship between the two pollutants. Over a period of time, developments in engine technology have allowed and continue to allow the trade-off curve to move to lower values of both NOx and PM. Developments in combustion systems, fuel injection equipment, turbocharging and associated control systems have enabled and contributed to this improvement. The chart on the left gives one view of the achievements and continuing potential of these engine-based developments. The trade-off thus gives engine developers the opportunity to combine the optimisation of 'raw' emissions and fuel economy with the optimisation of the emissions control system. In addition, the use of NOx aftertreatment can provide a positive influence on CO_2 emissions by allowing the engine to run at the best NOx and PM conditions for optimised fuel consumption.



Particulate Matter emissions



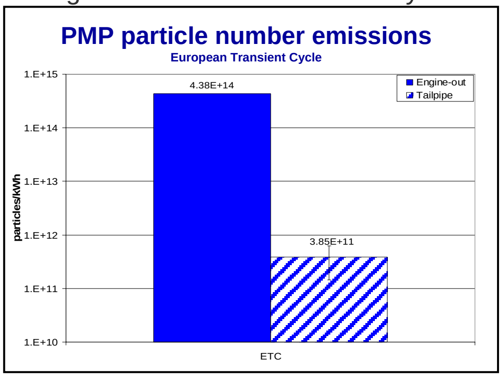
A key objective for exhaust emissions aftertreatment systems is to be able to offer similarly high levels of treatment efficiency irrespective of what levels of engine-out NOx and PM the particular engine achieves. For particulate matter, wall-flow particulate filters act on an essentially 'mechanical' principle and so their efficiency is not significantly affected by the levels of particulate in the feed gas, although higher levels will require more frequent regeneration to remove the carbonaceous material collected. The results of the AECC Heavy-duty Euro VI test programme demonstrated an efficiency for particulate mass removal of some 99.8%, leading to PM emissions levels over the European Transient Test Cycle (ETC) of only 1.0 mg/kWh despite comparatively high engine-out emissions of well over 500mg/kWh. The PM emissions levels achieved are thus one-tenth of the most stringent of the scenarios tabulated in



the Commission's consultation (Scenario A for CI: 0.010g/kWh PM). The particulate matter results are shown in the chart above.

In addition to measuring particulate mass, the AECC test programme examined the number of ultrafine particles emitted, using the methodology developed for the United Nations working group on the Particulate Measurement Programme (PMP)[2]. This test method is currently undergoing validation testing in a number of different laboratories. It is, however, similar in principle to the methodology developed under PMP for Light-duty vehicles, for which the inter-laboratory correlation exercise has been completed. The report on the Light-duty exercise[3] concluded that "The number method presents improvements over the mass method in terms of limit of detection, accuracy, discrimination power and variability when measuring a stable particle source. For these reasons, the number method is a superior alternative to the existing or a revised mass method for future regulatory procedures".

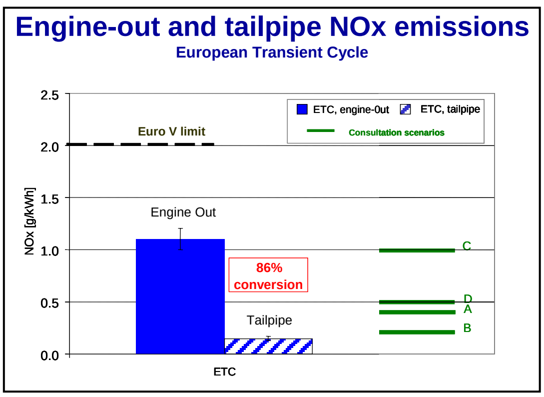
The AECC test programme showed that particle numbers at the tailpipe were reduced by 3 orders of magnitude over those emitted by the engine – an efficiency for ultrafine particle removal of over 99.9%. Particle number emissions were of the same order of magnitude regardless of the test cycle used, and analysis showed that the efficiency for removal of elemental carbon was in line with that for particulate mass and particle number removal, exceeding 99% efficiency for all the cycles tested. Further chemical analysis examined the effect on polycyclic aromatic hydrocarbons. These showed that the emissions control system provided similarly high levels of removal for these PAH emissions.



NOx emissions

The system of Selective Catalytic Reduction for the removal of NOx using urea as a reagent is already widely used in Euro IV and Euro V Heavy-duty vehicles in Europe. The motor industry[4] stated that SCR technology allows retention of engine calibrations that correspond to the best compromise between fuel consumption and the formation of pollutants during the combustion process. Thus it is, said ACEA, possible to comply with the Euro V emission standards and, at the same time, achieve fuel consumption levels which are 6% lower than those of equivalent Euro III engines. AECC demonstrated in 2002[5,6] that such a system applied to a Euro III engine could provide an 85% reduction in NOx emissions over the European Transient Cycle (ETC) test procedure. This was achieved even after durability testing equivalent to real-world driving of 250000km. The resulting NOx emissions at tailpipe were 1.0g/kWh which is half of the 2.0g/kWh requirements for Euro V, from an engine producing average NOx emissions of 5.86g/kWh.

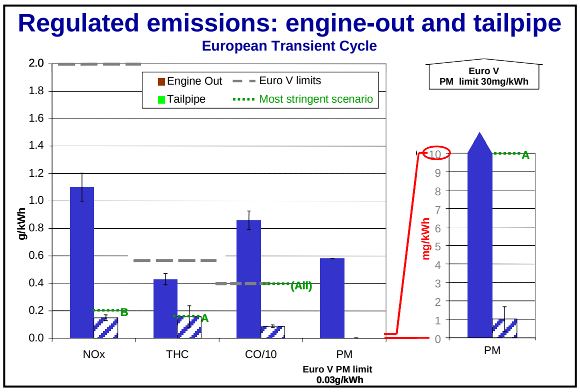
To apply this technology to the anticipated future generation of engines which will have lower engine-out NOx levels requires careful control of urea dosing levels, as the lower levels of engine-out NOx will demand a smaller optimal amount of urea. Commencing in mid-2006, the AECC Heavy-duty Euro VI test programme therefore conducted tests on a modern, commercially-available engine designed to meet the US2007 emission requirements. This engine had low engine-out NOx emissions of a little over half the requirements of Euro V. The emissions control system therefore utilised a urea dosing system developed for low levels of engine-out NOx.



The results confirmed that, with appropriate systems and calibration, the same percentage improvement can be obtained for engines with low levels of engine-out NOx emissions. Results produced over the ETC test were 0.15g/kWh NOx, which is comparable to NOx emissions levels achieved on tests of prototype EGR+DPF+SCR engine-aftertreatment systems by the motor industry [7]. This result would meet even the most severe NOx scenario in the Commissions public consultation (scenario B; 0.2g/kWh). These figures were achieved at the same time as meeting the more severe (scenario A) limit for PM and with a 3 orders of magnitude reduction in particle numbers.

CONCLUSIONS

The AECC Heavy-duty test programmes have demonstrated the capability of urea-SCR systems to provide an 85% reduction in NOx with the use of appropriately designed and calibrated urea-dosing systems. This same percentage reduction has been demonstrated on engines with widely-differing levels of engine-out NOx emissions. In conjunction with an engine itself having low emissions of NOx, any of the scenarios identified in the Commission's consultation could be achieved.



In conjunction with a wall-flow particulate filter, this system achieved emissions of particulate mass meeting even the most severe of the Commission's consultation scenarios.

Particulate Mass was reduced by 99.8% and particle numbers by 99.9%, 3 orders of magnitude. Hence particle emissions were virtually eliminated from the tailpipe. As may be seen from the graph on the left, there were also substantial reductions in CO and HC emissions.

The resulting combination of a low-NOx engine, an appropriate low-dose urea injection system and an emissions control system incorporating a particulate filter and SCR catalyst met, in a single step, the most stringent of the Commission's scenarios for each pollutant – scenario A for PM, THC and CO and scenario B for NOx.

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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, ceramic and metallic substrates and speciality materials incorporated into the catalytic converter and filter and catalyst based technologies to control diesel engine emissions (especially particulates and nitrogen oxides). Members' technology is incorporated in the exhaust emission control systems on all new cars and an increasing number of commercial vehicles, buses and motorcycles in Europe.

AECC's members are: Argillon GmbH, Germany; BASF Catalysts GmbH, Germany; Ceram Catalysts GmbH, Germany; Corning GmbH, Germany; Delphi Automotive Systems SA, Luxembourg; Emitec Gesellschaft für Emissionstechnologie mbH, Germany; Ibiden Deutschland GmbH, Germany; Johnson Matthey PLC, United Kingdom; NGK Europe GmbH, Germany; Rhodia Electronics & Catalysis, France; Saint-Gobain Industriekeramik Rödental GmbH, Germany and Umicore AG & Co. KG, Germany.

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[1] Ricardo, 13th Diesel Engine-Efficiency and Emissions Research (DEER), Detroit, 13 August 2007

[2] Andersson and Clarke UN-GRPE PMP Phase 3 - Inter-laboratory correlation exercise: Updated framework and laboratory guide for HD engine testing. 31 May 2005.

[3] Andersson, Giechaskiel, Muñoz-Bueno, Sandbach and Dilara, Particle Measurement Programme (PMP) Light-duty Inter-laboratory Correlation Exercise (ILCE_LD) Final Report, May 2007 final draft, UN-ECE.

[4] Selective Catalytic Reduction (Final Report): The most promising technology to comply with the imminent Euro IV and Euro V emission standards for HD engines. ACEA, 23 June 2003.

[5] Searles, Bosteels, Such, Nicol, Andersson and Jemma; Investigation of the Feasibility of Achieving Euro V Heavy-duty Emissions Limits with Advanced Emission Control Systems; FISITA paper F02E310, March 2002.

[6] Andersson, Jemma, Bosteels and Searles, Partikelemission eines EU 3 Heavy-duty Dieselmotors mit katalytischem Partikelfilter und selektiver katalytischer Reduktion: Größe, Anzahl, Masse & Chemie, Aachener Kolloquium, 2002.

[7] ACEA publication: Correlation ETC – WHTC (updated with additional information), http://www.acea.be/files/070531%20Correlation%20ETC-WHTC%20(plus%20additional%20data)%20FINAL.pdf