Progress in Emission Control Technology

A SELECTIVE REPORT OF THE SAE DETROIT MEETING

Traditionally, the Congress of the Society of Automotive Engineers (SAE), held each year at the end of February in Detroit, U.S.A., has been the magnet for people involved in all aspects of automotive engineering, including those concerned with emission control. The 1995 meeting, held from 27th February to 2nd March, will be the last occasion when emissions feature as part of the programme at the main Congress. Instead, in 1996, this topic will form a major part of two separate meetings to be held under the aegis of the Fuels and Lubricants Activity in the Spring and in the Autumn.

Nevertheless, at the Congress this year, there were a number of papers devoted to the control of emissions from both gasoline and diesel fuelled engines. Interest was focused principally on systems meeting the tightened legislative requirements appertaining to the U.S.A. and Europe between now and the year 2000.

This review can cover only a proportion of the papers presented, but they have been selected to show the principal trends in the ongoing developments of this area of technology.

Palladium-Based Three-Way Catalysts

There is a strong continuing development of new three-way catalysts based on palladium, either alone or in combination with rhodium and platinum. The excellent low-temperature performance and high-temperature resistance of palladium, coupled with its ability to reduce hydrocarbon species in the exhaust gas, make it an important component in systems designed for future U.S. and European applications. This was illustrated in a paper by Z. Hu and R. M. Heck (Engelhard) who described the performance of close-coupled palladium catalysts stabilised with base metal promoters on a vehicle in the FTP (Federal Test Procedure) test cycle, after extended ageing for 24 hours in air at temperatures up to 1050°C. The precise formulation of palladium-containing systems can depend on a number of factors, including performance requirements and fuel quality considerations. For example, previous studies have shown that the conversion performance for nitrogen oxides by palladium-only catalysts is more susceptible to poisons in the exhaust gas (fuel-derived sulphur and lead species) than is the conversion activity for hydrocarbon and carbon monoxide.

Rhodium is the metal normally used to enhance nitrogen oxides performance in autocatalysis, and R. J. Brisley, G. R. Chandler and colleagues (Johnson Matthey) described the development of a number of advanced palladium-containing formulations, based on optimisation of beneficial interactions of the noble metal and washcoat components. The authors found that palladium-rhodium formulations made in this way were particularly suited to close-coupled applications in markets where the availability of unleaded fuel is good, and where any trace lead levels are low (as in, for example, the U.K. and Germany). However, incorporation of some platinum to give a platinum:palladium:rhodium trimetal combination gives improved lead tolerance, and may be preferred – especially in cooler, underfloor locations – where the possibility of poisoning by residual lead exists.

A further advantage of the advanced high-palladium content catalysts is that they generate less hydrogen sulphide under rich conditions. Many current catalyst-equipped vehicles contain more than one catalyst unit, and benefits can sometimes be obtained by having different formulations on each brick. However, the same authors show that the balance of oxidants and reductants passing through each catalyst unit needs to be carefully considered if optimum performance of the complete system is to be obtained.

The advantages of adding rhodium and platinum to palladium in catalysts for European applications were also described by A. Punke, U. Dahle and colleagues (Engelhard), who showed that optimised trimetal formulations gave a better performance than either palladium-only catalysts, or the platinum-rhodium catalysts that are currently in use.

Cold Start Hydrocarbons Emission Control

The debate continues on the best means to control hydrocarbon emissions in the period before the main catalyst becomes fully operational, with a number of options still being considered. One possibility is to lower the light-off temperature of the catalyst itself. Advances in this area were reported by S. E. Golunski, H. A. Hatcher and colleagues (Johnson Matthey). Newly developed platinum/ceria-palladium technology offers substantially improved steady-state and dynamic light-off performance, compared to the palladium-only system. By combining this technology with low thermal mass substrates, and by utilising stoichiometric or lean cold start engine calibration strategies, the improved low-temperature performance of the new catalyst can be exploited.

Of the alternative ways to attack cold start emissions, a number of papers discussed electrically heated catalyst (EHC) technology, including ones from Corning, Grace, and a team from the German automobile manufacturers. It is clear that EHC based systems when used together with conventional catalysts are capable of meeting stringent legislative limits. However, the main concern remains the trade-off between electrical power and performance, and how that power should be generated.

Diesel and Lean Burn Engines

Emphasis on pollutant control from lean burn engines, whether diesel or gasoline, has focused on the removal of nitrogen oxides since the other principal pollutants, hydrocarbon and carbon monoxide, are normally easily removed under lean conditions. Nevertheless the catalytic converter on a diesel car has to operate under extremely variable conditions, ranging from low temperature during city driving to high temperature during motorway driving.

A paper by G. Smedler, G. Ahlström and co-workers (Johnson Matthey) described how the extremely good low-temperature activities for carbon monoxide and hydrocarbons, negligible sulphate storage and very good thermal stability, were combined in a catalyst, which also had good poison resistance and high lean nitrogen oxides performance, by controlling the interactions between the components in the platinum group metal based catalyst.

Several authors, including M. Iwasaki, N. Ikeya and co-workers (Ishikawajima-Harima Heavy Industries Co. Ltd.) described the good properties of platinum catalysts for nitrogen oxides removal under lean conditions, especially their stability, when water vapour and sulphur compounds are present, and lack of choking by carbon formation. However, they identify a need to improve the catalyst against nitrous oxide formation.

Two papers concerned with gasoline fuelled lean burn engines were presented. The first by N. Miyoshi, S. Matsumoto and colleagues (Toyota) and K. Kasahara (Cataler) described the mechanism of nitrogen oxides storage under lean operating conditions, the subsequent release and conversion, as the engine returned to stoichiometric control. This concept could enable the fuel economies of the lean burn engine to be combined with a good overall control of nitrogen oxides. This study used a $Pt/Ba/Al_2O_3$ catalyst, and it was postulated that an intermediate nitrate species is formed as the platinum catalyses nitric oxide oxidation to the dioxide.

The second paper, by A. Takami, T. Takemoto and colleagues of Mazda, described a new type of three-way catalyst containing platinum, rhodium and iridium as the active metals which, on a vehicle alternating between lean and stoichiometric conditions on the Japanese 10-mode cycle, achieved a significant reduction in nitrogen oxides. This area of gasoline-lean nitrogen oxides has received relatively little attention, and will be of interest for the future.

In summary, the 1995 SAE Congress continued to show the importance of catalyst solutions to combat automotive exhaust pollutants, and that platinum group metals will remain at the heart of that strategy. D.E.W.