Emission Control Technology

PROGRESS REPORTED AT THE SPRING SAE CONFERENCE

It was unusually warm during the traditional end-of-February Congress of the Society of Automotive Engineers (SAE), held this year from 24th to 27th February – there was no snow on the downtown Detroit streets! This Spring conference is the major, general SAE conference covering all aspects of automotive engineering, with over 47,000 delegates attending this year. Fine weather and a broad range of interesting papers concerned with exhaust after-treatment made this a memorable event for those concerned with emissions control, and the continuing importance of developments in this area was reflected in the high attendance at the sessions.

Space prevents a review of all the relevant papers, so a selection has been made to illustrate the direction catalyst technology is taking in response to increasingly stringent legislation on emissions. Reference numbers of the original papers are given in parentheses.

Autocatalyst formulations have become more complex over recent years and may, for example, involve separated platinum metals each with an optimal promoter package. A paper by Degussa (960802) gave some insight into the design of such formulations, and a comprehensive study by Volvo (960801) of reactions over a double-layer trimetal (platinum-palladium-rhodium) catalyst enabled a dynamic kinetic model to be developed, which included sulphur dioxide effects.

Solving the Cold Start Problem

Starter Catalysts

Reduction of emissions during the "cold start" period is the key objective for meeting future regulations, and the use of low temperature light-off catalysts mounted close to the exhaust manifold to decrease warm-up time is an attractive approach for achieving this. However, operation in this position demands particularly good thermal durability of the catalyst. Space constraints often preclude location of large volume close-coupled catalysts near the exhaust manifold, and combinations of a small close-coupled starter catalyst with a larger underfloor unit can provide an effective system.

Toyota (960797) explored the effectiveness of such two-catalyst systems, and Johnson Matthey (960799) demonstrated that both the U.S.A. LEV/ULEV and European Stage 3 standards can be met with suitable high-activity catalysts of good thermal durability.

The attainment of low emission levels depends on rapid warm-up of the front catalyst and the presence of a sufficiently large total catalyst volume to maintain performance under normal operating conditions. Audi (960261) stressed the roles of engine management in rapid heating, and secondary air injection to enhance catalyst light-off. Starter catalyst performance depends on several parameters: a small volume heats up quickly, but a larger volume produces a greater exotherm (temperature rise), and this is reflected in the accumulated hydrocarbons emissions during a test cycle. Starter catalyst cell density also affects performance: there is a monotonic improvement as it increases. However, when a starter catalyst is combined with an underbody catalyst the system performance is less dependent on the characteristics of the starter, provided that it quickly gives a sufficient exotherm to light-off the main catalyst.

Metallic monoliths have typically been used in starter applications, and Corning (960262) reported a comparison of ceramic and metal foil-based starter catalysts. From their tests, they concluded that with the same outside diameter and back-pressure characteristics similar emission and durability performance can be obtained. Corning (960349) and NGK (960565) reported additional thermal durability results for ceramic monoliths in close-coupled locations. The latter proposed a design using a dual cone structure for both the converter inlet and outlet to minimise heat conduction, thus decreasing the temperature of the surrounding mat and lowering the surface temperature of the converter to below 450°C – when the catalyst itself is at a temperature of 1050°C.

Electrically Heated Catalysts

An alternative approach for reducing cold start emissions is to preheat electrically a small platinum group metal containing catalyst in front of the main catalyst. High electrical power requirements have tended to inhibit adoption of this concept, but the first electrically heated catalyst (EHC) application was described by Alpina/BMW and Emitec (960349), and it is interesting to note that, on the car which they describe, the power is switched between two EHCs on either side of the engine in order to minimise power consumption.

Emitec (960339) presented a separate paper on the general applicability of foil-based EHCs, and W. R. Grace (960341) also presented system performance with related EHCs. Honda (960342) compared foil-based and extruded EHCs in vibration, heat impact and distortion durability tests, and discussed the use of battery and alternator power supplies. They opted for a special alternator. In contrast, Hyundai (960350) investigated characteristics of both conventional lead/acid and nickel/metal hydride batteries for supplying EHC current, and concluded that the latter has significant attractions – as lead/acid batteries do not sustain the necessary heavy current/depth of discharge over many cycles.

NGK (960340) gave details of the design concepts and durability data of extruded metal EHCs and Corning (960345) presented vehicle durability results for their latest EHC design. Clearly, EHC-based technology has been developed to a stage where it could be used in series production, but it appears that in practice passive starter catalysts are more favoured, due to their not needing associated equipment.

Lean-Burn Technology

Catalysts for lean-burn engines are likely to become increasingly important; a concern here is NOx reduction in the presence of excess oxygen. Orbital (960361) highlighted the fact that extremely lean operation of a direct injection stratified charge two-stroke engine results in inherently low NOx levels, while Degussa (960133) showed how zeolite can be used to store and activate hydrocarbons in diesel engine exhaust during the start-up phase. This improves NOx reduction. Corning (960343) described a by-pass system (two conventional ceramic platinum group metal catalysts and an adsorber) in which zeolite is used to absorb hydrocarbons during the cold start of a conventional gasoline engine. They also described (960348) an in-line adsorption system which uses a flow of air to prevent exhaust gas passing through a central bypass in an adsorber monolith during start-up.

Developments in Sensors

Sensors are important for the correct operation of emission control systems. Oxygen sensors are used to maintain accurate air/fuel ratios, and in the future it seems likely that other types of sensors will be needed. Several reports were concerned with other sensors: Matsushita/Panasonic described (960336) a wide range thermistor for exhaust gas temperature measurement. NGK reported a new high performance platinum resistive temperature sensor (960333), and discussed its possible use in on-board diagnostic applications in which the predicted temperature rise on a catalyst is compared with the corresponding measured increase.

Another NGK paper (960334) described a new NOx electrode; this multi-layer zirconia system, operating at 600 to 700°C, involves oxygen pumping with platinum electrodes and, in a separate zone, dissociation of nitric oxide takes place over porous rhodium. The oxygen formed is measured with an oxygen electrode, and the concentration is found to be proportional to the amount of NOx originally present. Gold is used to inhibit nitric oxide dissociation on platinum electrodes, and to improve off-set current characteristics.

Thus, once again the SAE conference has highlighted the key role played by the platinum group metals in emission control technology, and has demonstrated the amount of worldwide effort and expertise committed to improving the performance of emission control systems. M.V.T.