reduction in carcinogenic formaldehyde emissions.

In the area of diesel exhaust control, B. J. Cooper and J. E. Thoss of Johnson Matthey demonstrated that excellent particulate trap regeneration could be achieved, below 300°C, by the use of a platinum-based diesel catalyst (SAE 890404). Furthermore, it was also proven that the catalyst did not have to be in direct contact with the diesel particulates for combustion of the particulates to be initiated. However, the disadvantage of this catalyst system was its tendency to produce high levels of sulphuric acid emission, due to the conversion of fuel sulphur to sulphuric acid over the catalyst. It was, therefore, recommended that significant reductions in diesel fuel sulphur should be made to take advantage of the particulate combustion capability of such a system.

Air : Fuel Ratio Sensors

The use of catalysts in wide-range air : fuel ratio sensors, to expand the detection range in the rich air : fuel region, was described by H. Tanaka, S. Nishimura, S. Suzuki, M. Miki, T. Harada, M. Kanamaru, N. Ichikawa and S. Ueno, of Hitachi Limited (SAE 890299). The paper concluded that the limiting cause of detection in the rich air : fuel ratio region can be identified as insufficient combustion of carbon monoxide and hydrogen with oxygen on the electrode, thus preventing the realisation of a diffusion limited state which is necessary to detect the air : fuel ratio. This situation was corrected by applying an improved diffusion layer to decrease diffusion and increase combustion rate in an improved platinum electrode. It was demonstrated that the detection limit could be expanded to $\lambda = 0.6$ whereas that of a conventional system is $\lambda = 0.8$.

Conclusion

Overall, the papers presented at this Congress reflected the continuing high level of research and development involving the use of the platinum group metals for vehicular emission control. The developments in substrate technology, substrate coating interaction, new techniques for cold-start emission control, the use of catalysts and catalyst design for the control of currently unregulated emissions, the use of platinum catalysts for diesel emissions control, and the use of platinum catalysts for improved sensor performance all show that significant advances in catalytic devices continue to be made. B.J.C., R.M.K.

Fuel Cell Developments and Future Potential

The nineteenth century invention and twentieth century development of fuel cell technology are admirably covered in a recent review (S. Srinivasan, *J. Electrochem. Soc.*, 1989, **136**, (2), 41C–48C). The key feature of a fuel cell system is the electrochemical cell stack, and its components include the porous gas diffusion electrodes, the electrolyte and the bipolar plate, and these are determined largely by the primary fuel and by the temperature and pressure of the system. Unless very high operating temperatures are used the performance of the electrodes depends upon the characteristics of the electrocatalyst, and platinum or a platinum alloy is generally used.

The pioneering work of F. T. Bacon in the early 1930s served as the foundation for the fuel cells that successfully provided auxiliary power on the Apollo space vehicles. Fuel cells developed from these earlier models provide the main electrical power supplies for the Orbitor space shuttles, and their success has led to a European programme to consider fuel cell generators for the Hermes reusable space craft.

The energy crisis of 1973 gave a significant boost to the development of fuel cells for terrestrial applications, and the continuing need to conserve petroleum fuels reinforced by the current interest in low pollution energy generation has helped to sustain major development programmes in America, Japan and Europe.

This useful review concludes by giving a most interesting prognosis of the economics and applications of fuel cell systems, and therefore at least in the short to medium term for platinum-containing electrocatalysts. It is suggested that lower manufacturing costs and higher fossil fuel prices make fuel cell systems most attractive for terrestrial use in the developing countries.