Automobile Exhaust Emissions Control

LEGISLATION TO PROTECT THE EUROPEAN ENVIRONMENT

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Catalyst technology based upon platinum metals supported on a ceramic or metal substrate has been tried, tested and approved in the United States of America and in Japan for the control of carbon monoxide, unburnt hydrocarbons and oxides of nitrogen from vehicles. Australia is shortly to require a reduction in noxious emissions from this source, while in Europe a growing awareness of the detrimental effects of pollutants upon the environment has now led to a decision to introduce emission control standards. Over the past decade the motor industry has been supplied by Johnson Matthey with many millions of autocatalysts; now their accumulated expertise and manufacturing capacity will be available to meet the European demand, whether it be for advanced three-way catalysts, using platinum and rhodium, or for platinum + palladium oxidation catalysts to support anticipated developments in lean-burn engine technology.

On the 29th June 1985 European Environment Ministers meeting in Luxembourg agreed on exhaust emission standards for motor vehicles that, when enacted, will define a market in Europe for emission control systems. This agreement ended a prolonged discussion on the levels at which future standards for Europe should be set. The new emission standards will be brought in over a five-year period commencing on the 1st October 1988. From that date new models of cars with engine capacities greater than 2 litres will have to meet the agreed standards in all European Economic Community (E.E.C.) countries that adopt the new directive. While a particular control system has not been specified, these cars are likely to use the rhodium+platinum three-way catalyst technology that is already widely used in the United States of America and in Japan to control carbon monoxide, hydrocarbon and nitrogen oxide emissions (1). For cars with smaller engines less severe standards have been set, and it will be possible to meet these using alternative technologies. In particular it is expected that lean-burn engines producing significantly lower amounts of nitrogen oxides will be developed, but in all probability these will have to be fitted with an oxidation catalyst to control carbon monoxide and especially the levels of hydrocarbon emissions associated with lean-burn engines. These catalysts are likely to be based on platinum and palladium, and the use of either catalyst is made possible by the fact that unleaded petrol must be introduced throughout the E.E.C. for all new model cars to use by 1st October 1989, at the very latest. Indeed a number of European countries are already encouraging the earlier introduction of unleaded petrol.

West German Initiatives

Consideration of exhaust emission standards for motor cars that could use platinum metal catalysts for their control started in Europe as long ago as July 1976. The Federal Republic of Germany's Environmental Agency, the Umweltbundesamt (U.B.A.), published a paper that proposed the application from 1980 of

Fig. 1 Close collaboration between motor manufacturers and catalyst suppliers ensures optimised use of catalyst technology. Here a Ford Sierra is undergoing test on a rolling road dynamometer at the Emission Test Laboratory of Johnson Matthey Chemicals Limited where carbon monoxide, hydrocarbon and nitrogen oxide emissions can be continuously measured as a vehicle is put through a specified driving schedule. Catalyst durability and performance may also be assessed by running a test vehicle on a road circuit

tighter exhaust emission standards. These standards would meet the goals set by the Federal Republic's Government in 1971, which sought a 90 per cent reduction in the pollutants emitted by motor vehicles from 1969 levels. The U.B.A. generated the data necessary to set the proposed standards and conducted a technical evaluation of methods available to meet them. One of the methods proposed was the use of lead-tolerant catalysts, because at that time it was considered unlikely that unleaded petrol would be available on a widespread scale in Europe. These proposals initiated programmes of work by the catalyst industry which have been reported previously (2).

Pressures for Unleaded Petrol

In Europe, at present it is still standard practice to add lead to petrol to improve the octane rating and its presence would cause the rapid poisoning of any catalyst. Thus consideration of the platinum metal catalyst technology developed for markets in the U.S.A. and Japan was not seriously possible in Europe until April 1983 when a Royal Commission report entitled "Lead in the Environment" was published in the United Kingdom (3).

This included among its recommendations that the Government should begin urgent discussions with the U.K. oil and motor industries in order to agree a timetable for the introduction of unleaded petrol. In announcing the report to the U.K. Parliament, the Secretary of State for the Environment said that the Government accepted in full the findings of the Royal Commission and that it would seek, on health grounds, in consultation with its European partners, to reach agreement on a date for a pan-European introduction of unleaded petrol. The target date for reaching that agreement was 1989.

During the same period there was considerable political activity in the Federal Republic of Germany. The ecological Green Party was

Agreed European Automobile Emission Control Standards					
Engine capacity	Date of introduction		Emissions, grams/ECE Test		
	New models	All new cars	Carbon monoxide	Hydrocarbons and nitrogen oxides	Nitrogen oxides
Over 2 litres	October 1988	October 1989	25	6.5	3.5
1.4–2 litres	October 1991	October 1993	30	8	–
Less than 1.4 litres:					
First stage	October 1990	October 1991	45	15	6
Second stage	October 1992	October 1993	To be decided by 1987		
	(latest dates)				

already gaining major support and there was public concern at reports that acid rain was destroying German forests. The motor car was cited as a major contributor to acid rain and on 20th July 1983 the Cabinet of the Federal Republic of Germany announced legislation that would require all new cars registered in Germany from 1st January 1986 to be engineered to operate on unleaded petrol and to be fitted with catalysts. After much subsequent discussion this was confirmed in a decision of 26th October 1983 which stated that unleaded petrol and an approximately 90 per cent reduction in car exhaust emissions using "best current technology" were to be enforced from 1st January 1986. This Cabinet decision stated that current U.S. Federal standards and test procedures were to be used, which effectively specified the use of rhodium+platinum three-way catalysts. This set the scene for further discussions in Europe.

The European Debate

The major arenas for debate and negotiation on emission standards have been the European Commission in Brussels and meetings of the Council of Ministers of the E.E.C. who come together twice yearly immediately prior to the biannual summit of European Heads of Government. At these meetings there has been a wide diversity of opinion on the need for tighter emission standards in Europe, ranging from those countries who proposed a marginal tightening of current emission standards through to Germany demanding full U.S. standards. Following meetings in December 1984 and March 1985 a compromise agreement was reached which attempted to balance the commitment of the Federal Republic of Germany and its supporters to U.S. standards against the view of the U.K. Government who, although it was at the forefront of the move to unleaded petrol, has been opposed to insistence on three-way catalysts as implied by the German proposals. The U.K. Government was concerned that such regulations would stifle the development of lean-burn engines which it believes will offer fuel economy advantages.

A Framework for Agreement

The 1985 March agreement set the principles of a political framework for a European standard based on the current European emissions test procedures, but which would have an effect on the European environment equivalent to that produced by U.S. standards.

For cars over 2 litres it was anticipated that this would mean the use of three-way catalysts, while for medium sized cars from 1.4 to 2.0 litres engine capacity the European standards would also encompass the use of lean-burn engines coupled with oxidation catalysts. For small cars, below 1.4 litres, tighter emission standards are to come in two stages, the first stage requiring only engine modifications while the standards for the second stage are to be agreed by 1987. A

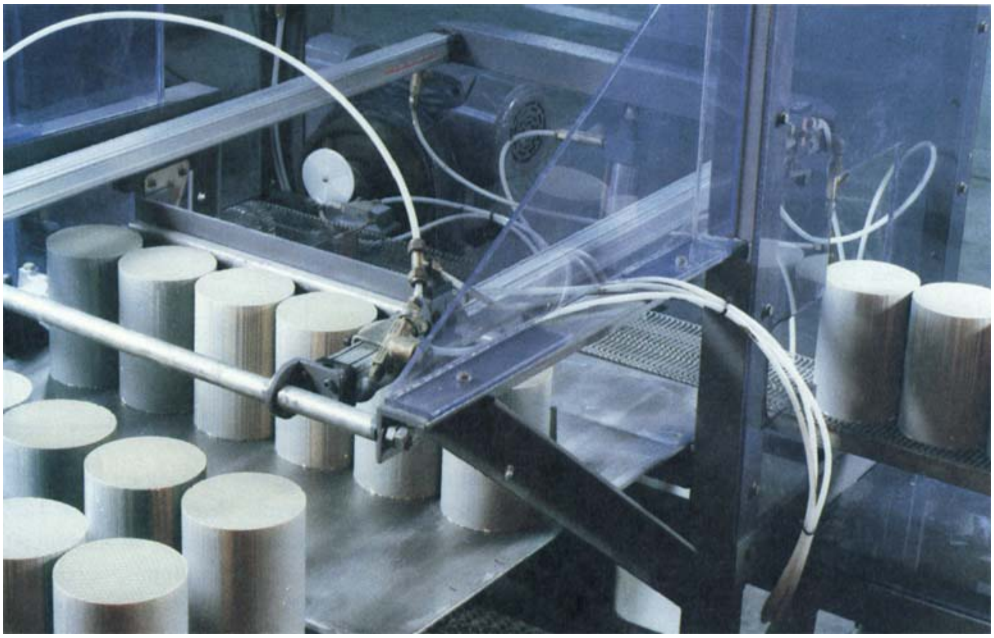

Fig. 2 Since 1974 Johnson Matthey has been supplying the motor industry with emission control catalysts for cars sold in the U.S.A., Japan, Australia and, increasingly, for German, Austrian and Swiss markets, from manufacturing facilities in both England and the U.S.A. The autocatalyst units shown here during processing at the Royston factory consist of ceramic honeycomb monoliths which form a lightweight, high surface area support upon which a high surface area washcoat is deposited prior to coating with the finely divided platinum metals that catalyse the destruction of the exhaust pollutants

June meeting was set to agree the levels of pollution that cars would be allowed to produce in order to meet the framework of agreement from the March meeting. This proved to be more difficult than at first thought and although the European Commission had earlier proposed a set of numbers, these were regarded as either being too severe or not severe enough.

The final agreement can be summarised by the data in the Table.

The agreement reached was, in the case of the United Kingdom, only for consideration and subject to a general reserve by Denmark who would not agree to any standards less severe than current U.S. standards. The United Kingdom in fact confirmed its agreement to the standards in early July.

For cars of 1.4 to 2.0 litres in capacity the standards have been carefully chosen to meet the original directive of the European Commission which stated that they should be achievable to the maximum extent possible at reasonable cost and by different technical means. In particular it should be possible to satisfy the standards by simple lean-burn techniques, combined with an oxidation catalyst.

Lean-Burn Engines

Lean-burn engines have been under development since the 1970s. The diesel engine is a successful example of a true lean-burn engine. It was in recognition of the advantages of diesel engines in terms of fuel economy and lower levels of nitrogen oxide pollution that emissions engineers in the motor industry sought to produce petrol engines that would operate with air:fuel ratios as lean as those possible in a diesel engine. At air:fuel ratios greater than 20:1 the production of nitrogen oxides is considerably reduced and better fuel economy is obtained. However, emissions of hydrocarbons increase. There is, however, sufficient excess oxygen in the exhaust gas to enable those hydrocarbons to be removed simply by fitting an oxidation catalyst into the exhaust system.

The challenge for the engineer is to maintain combustion and driveability at these lean air: fuel ratios. This is achieved by encouraging turbulence in the engine's cylinders and by the propagation of a large flame area at early stages of the combustion process. Heat losses from the engine are minimised by designing the combustion chamber with a minimum surface area: volume ratio. Also, to ensure good combustion it is necessary to produce a high energy spark.

Conclusions

The motor industry now has two alternative technologies to meet the new standards. Already in the Federal Republic of Germany, where there are fiscal incentives to encourage the sale of "clean" cars by collecting lower road tax, three-way catalyst cars are being sold and unleaded petrol is widely available. Undoubtedly some car manufacturers will opt for this proven route, and particularly for cars greater than 2 litres the three-way catalyst using platinum promoted by rhodium will be the preferred choice. For smaller cars, the choice is between the lean-burn engine, fitted with a palladium-promoted platinum oxidation catalyst and the three-way catalyst with an engine fuel management system controlled to ensure that the exhaust maintains the stoichiometry necessary for efficient operation of the three-way catalyst.

References

1 B. Harrison, B. J. Cooper and A. J. J. Wilkins, *Platinum Metals Rev.*, 1981, **25**, (1), 14
2 A. F. Diwell and B. Harrison, *Platinum Metals Rev.*, 1981, **25**, (4), 142
3 "Royal Commission on Environmental Pollution", 9th Report, April 1983, H.M.S.O.
4 Press Release 7803/85, European Commission, 27/28 June 1985

Space Station Auxiliary Propulsion Jets

Resistojets have characteristics that make them attractive for space station auxiliary propulsion systems. For this arduous application the resistojet must have the capability of functioning with a variety of onboard propellants such as carbon dioxide, methane, hydrogen, ammonia and hydrazine.

Because of its excellent resistance to corrosion and high temperature oxidation, platinum has previously been considered for a similar application, but pure platinum was found to have inadequate strength. Many rhodium-platinum alloys are stronger, but in carbon dioxide at temperatures above 1200°C a volatile rhodium carbonyl compound forms and this loss of rhodium weakens the alloy. After extended operation at high temperatures platinum and its alloys also experience grain growth, which results in reduced stress-rupture performance, the formation of voids and physical distortion. It was for these reasons that grain stabilised platinum metals were developed in the late 1960s and early 1970s, primarily for use in the glass industry.

The preliminary results of compatibility experiments made to determine the effects of different propellants on platinum stabilised with 0.6 per cent yttria have recently been reported by M. V. Whalen, S. P. Grisnik and J. S. Sovey of the National Aeronautics and Space Administration, Lewis Research Center, Cleveland, Ohio, U.S.A. ("Compatibility Experiments of Facilities, Materials, and Propellants for Electrochemical Thrusters", NASA Tech. Memo. 86956, 1985, 16 pp).

For the tests, which generally lasted for 100 hours, annealed tubes of grain stabilised platinum were formed into coils. When surrounded by a flow of carbon dioxide, hydrogen or ammonia, an electric current was passed through the coils heating them to 1300°C, a typical operating temperature for resistojet heaters. Coils were also tested in a flow of methane and in mixtures of carbon dioxide and methane while heated at 500 to 600°C, a range chosen to avoid carbon deposition.

Measurement of mass losses after testing indicated a minimum life of 100,000 hours, which exceeded by a factor of ten the life required for the potential space application. Some corrosion of the surface occurred during heating in hydrogen and more especially in the ammonia environment. While grain stability was apparently not affected during these short-term tests, the results of long-term exposure to reducing atmospheres has yet to be determined.