diesel applications. This had a platinum pre-oxidation catalyst, a hydrolysis catalyst and a vanadium-based SCR catalyst, followed by a platinum guard catalyst to prevent traces of ammonia from escaping into the environment by oxidising it to NO which is environmentally less sensitive. Using a simple urea dosing strategy a NOx reduction of 77% was recorded in the ESC test procedure (European Stationary Cycle, a heavy-duty diesel test cycle).

Mack Truck and Siemens (2000-01-0190) reported results for an American 12 litre heavy-duty diesel engine, and a Class 8 truck equipped with a vanadium SCR system. This returned NOx reductions averaging 65% in road tests, with a urea solution consumption of a little less than 100 mpg, and with another catalyst 140 mpg based on OICA test cycle data (Organisation Internationale des Constructeurs d'Automobiles, a heavy-duty diesel test cycle).

Johnson Matthey (2000-01-0188) described a urea-based SCR unit integrated with a CRT™. Combined particulate and NOx control was evaluated on several engines over a number of different test cycles. Simultaneous NOx conversions of 75–90% and particulate control up to 90% on current engines in both American and European test procedures were measured. A platinum oxidation catalyst was used before the particulate filter, SCR catalysts after ammonia injection for NOx reduction, and a platinum oxidation catalyst to control ammonia slip. The platinum pre-catalyst significantly enhances low temperature SCR performance by converting some NO to NO_2 which reacts faster, perhaps via reactive surface species of a N_2O_3 type. Although many challenges have to be overcome, SCR systems have demonstrated high efficiencies for NOx reduction, and in combination with particulate control capability, the way towards ultra clean diesel engines is being defined.

Conclusions

Emissions of exhaust pollutants from internal combustion engines in automotive applications have been dramatically reduced over recent years. This trend continues, and new technologies are being successfully developed to meet increasingly demanding requirements. The Detroit 2000 SAE Congress provided a focus for discussion about these developments, and confirmed the critical role PGM-containing catalysts have in this important area.

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References

1 "Diesel Exhaust Aftertreatment 2000", SP-1497; "General Emissions Research", SP-1506; "LEV-II Emissions Solutions", SP-1510; "Advanced Catalysts Substrates and Advanced Converter Packaging", SP-1532; "Exhaust Aftertreatment Modeling and Gasoline Direct Injection Aftertreatment", SP-1533. These and individual technical papers are available from SAE, 400 Commonwealth Drive, Warrendale, PA 15096, U.S.A. See also: http://www.sae.org

2 M. V. Twigg, *Platinum Metals Rev.*, 1999, 43, (3), 119

3 "First International Conference on Health Effects from Vehicle Emissions", London, 16–17 February 1999; see also J. P. Warren, *Platinum Metals Rev.*, 1999, 43, (2), 71

4 See papers in: "In-Cylinder Diesel Particulate and NO Control 2000", SAE SP-1508 (2000)

5 In the U.K. diesel fuel typically now contains less than 50 ppm sulfur

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HEALTH EFFECTS OF VEHICLE EMISSIONS

A REVIEW FROM THE SECOND INTERNATIONAL CONFERENCE

The Second International Conference on Health Effects of Vehicle Emissions was held in London from 23rd to 24th February, 2000. Some 165 delegates from 16 nations, and a variety of industrial, environmental, government and academic backgrounds, met to discuss issues concerned with reducing the environmental impact and health risks associated with vehicle emissions.

J. Wallace (Ford, U.S.A.) summarised some U.S. steps with respect to vehicle emissions. Since 1966 vehicle emissions have been reduced by a factor of 25. Hydrocarbon emissions have decreased by

96% and NOx (nitrogen oxides) by 75%, although the number of cars being sold every day is increasing. Overall in the U.S., vehicle miles travelled have increased by 127%, but net emissions have decreased – by 31%. Ford are working on Alternative Fuel Vehicles (AFVs) and the Ford "TH!NK" group investigates ideas to lower vehicle emissions. Ford has a commitment to fuel cell technology, as shown by projects such as the P2000 hydrogen fuel cell vehicle and the Focus FC5 methanol reformate vehicle.

M. T. Oge (EPA, U.S.A.) discussed improved U.S. air quality. Mobile sources contribute one third of the volatile organic compounds (VOCs), one quarter of the particulate matter (PM) and 40 to 50% of NOx to air pollution in urban areas. As data become available, standards will have to be updated. The emission of air toxics (such as benzene and formaldehyde) should be addressed by standards aimed at lowering them, as follows:

(i) reduce air toxics from the new fleet

(ii) introduce a voluntary retrofit programme for heavy-duty diesel vehicles, and

(iii) improve characterisation of mobile source toxic exposure: data for modelling purposes.

International Air Pollution Issues

M. P. Walsh (International Consultant, U.S.A.) discussed concerns and regulation trends associated with vehicle emissions (1). Progress has been made with air pollution in the U.S.A., Europe and Japan, by use of unleaded gasoline and catalyst technology, but PM emissions are an issue, with a diesel vehicle emitting more PM_{10} (PM of < 10 μm in diameter) than a gasoline vehicle. However, the larger number of gasoline vehicles together emit roughly three times more mass of PM_{10} than diesel.

In the U.S.A. by 2004, federal "Tier 2" standards and low sulfur gasoline will be phased in with a programme aimed at heavy-duty diesel vehicles. This will be introduced with tighter heavy-duty PM and NOx standards. Legislation to reduce the sulfur content in diesel is likely. It is hoped that sulfur levels will be reduced to 10 ppm. Particle filters for ultra fine particles will be used in future.

H. Tsuda and F. Okada described the Japan Clean Air Programme which aims to reduce emissions and improve air quality by 2010, and investigate and develop future vehicle and fuel technologies. It is hoped that tailpipe emissions from gasoline vehicles can be reduced by 70% from 2000–2002 (Step 1) with further reductions by 50% between 2005–2007 (Step 2), while for diesel it is hoped that tailpipe emissions can be reduced by 50% between 2007–2009.

The Canadian aim of reducing the ambient levels of $PM_{2.5}$, over a 24 hour average, to 30 $\mu g\ m^{-3}$ by 2010, and ozone levels to 65 ppb by 2015, measured over an 8 hour average was described by B. McEwan and M. Tushingham (Environment Canada). Canada requires sulfur levels in gasoline fuel to be no higher than 170 ppm by 2004 with a further reduction to 40 ppm from 1st January 2005.

Air pollution and control in north east U.S.A. were discussed by M. Treadwell (NESCAUM, Northeast States for Coordinated Air Use Management). There is little information about health effects from emissions, such as benzene, formaldehyde, 1,3-butadiene and acetaldehyde. Ambient concentrations of these air toxics currently exceed most cancer risk thresholds in the majority of north east areas. Mobile sources could account for 80 to 90% of primary emissions.

Sources of Pollution

Professor R. Harrison (University of Birmingham, U.K.) discussed U.K. pollutants. Based on data from 1996: 47% of the NOx, 71% of the CO and 30% of VOCs in ambient air are from road transport. For PMs, 25% of PM_{10} in the atmosphere was due to road traffic exhaust, increasing to 77% in the London area; 31% of $PM_{2.5}$ and 60% of $PM_{0.1}$ come from road transport.

R. Edwards and K. Koistinen (National Institute of Public Health, Finland) pointed out that in-vehicle concentrations of VOCs are 3 to 8 times higher than ambient levels, and a significant contribution to VOC compounds indoors is associated with traffic emissions.

The problems in measuring particle emissions were discussed by J. Andersson (Ricardo Consulting Engineers, U.K.). Present testing methods for light-duty particulate sampling are not ideal and a system representing real world conditions is needed. It was suggested that gasoline vehicles do not emit carbonaceous particles.

Health Effects

A. Peters (GSF, Institute of Epidemiology, Germany) presented evidence which related disease type, such as respiratory and cardiovascular, and trends in increases in mortality and hospital admissions, to air-borne particulate matter. Current data do not reflect the impact of urban air pollution.

Professor K. Donaldson (Napier University, U.K.) described the penetration depths of particles in the lungs. Particles, 0.01–0.1 μm in diameter, are thought to cause real problems. The lungs can deal more efficiently with larger particulate, such as PM_{10}, which is more detrimental to the upper airways. Particle surface area and size distributions should be considered in setting legislation.

Solutions

A. Friedrich (UBA, Federal Environmental Agency, Germany) stressed that for improved standards an increased public awareness, financial incentives to aid the introduction of cleaner vehicles and retrofitting programmes were needed. He emphasised NOx and PM diesel emissions and described the vanadium-based selective catalytic reduction (SCR) and NOx adsorbers. Detrimental effects to diesel particulate filter systems are caused by the sulfur in fuel, which requires reduction to at least 50 ppm and preferably to 10 ppm.

Changes in engine and chassis design to reduce vehicle emissions were described by K.-P. Schindler (Volkswagen, Germany). Customers are important, but car manufacturers have to obey legislation. Reducing drag, friction and vehicle mass can be critical in achieving reduced emissions, besides improving powertrain efficiency, by using Turbo Diesel Injection (TDI) with a high pressure injector, Gasoline Direct Injection, alternative fuels and fuel cell technologies. The VW vehicles Lupo 3L TDI and 1.4L FSI (Fuel Stratified Injection) are being developed. Aftertreatment technologies, particularly NOx storage catalysts and diesel particulate filters, such as the Johnson Matthey continuously regenerating trap (CRT™) were discussed.

Developments in conventional fuels were examined by J. Unsworth and A. Clarke-Sturman (Shell, U.K.). Lead in gasoline has been dramatically reduced, while MTBE use (to improve octane) increased when restrictions on the aromatic content of gasoline were introduced in January 2000. Shell propose that the European oil industry should address this. Problems with electrical conductivity and lubricity have occurred due to the lower sulfur content in fuel.

Catalyst aftertreatment systems and their operation, for instance continuously regenerating particulate traps and SCR technology and the need for retrofitting were discussed by R. A. Searles (Association for Emissions Control by Catalysts, Belgium).

"Conventional" and "advanced" diesel technologies were compared by J. Toulmin (BMW, U.K.) with respect to particulate emission. Both technologies emitted PM in the same size range but the "advanced" diesel emitted fewer particles on average. More research is needed on the relationship between particle number and mass emissions.

Conclusion

It is clear that more data are needed for better analysis of results and modelling purposes. The level of sulfur in fuels and its effect on catalyst systems, and particulate emissions from gasoline vehicles were contentious issues, with some supporting the need for technology to deal with the latter issue, while others suggest it is insignificant. With the predicted growth in population and continued increase in miles travelled, oil companies, and vehicle and aftertreatment-technology manufacturers will have to cooperate to improve upon achievements already made. Governments must provide legislation, information and incentives to encourage the application of future vehicle emission technologies. J. M. McNAMARA

Reference

1 M. P. Walsh, *Platinum Metals Rev.*, 2000, 44, (1), 22

John McNamara is a research scientist at the Johnson Matthey Technology Centre. He is working on the development of a method of aftertreatment of particulate emissions from gasoline-powered automotive vehicles.