

**Real Drive Emissions (RDE) and NO<sub>x</sub> and Particulate Control**  
**Monday 20 – Friday 24 May 2019**  
**Programme**

**Monday 20 May**

**Real-world driving for SI and diesel vehicles, fuel economy and emissions I**

- 08.00 Registration and coffee
- 08.30 **Introduction to the environmental problems of vehicle emissions including GHGs and Real World Driving**  
**Professor Gordon Andrews, School of Chemical and Process Engineering, University of Leeds**  
The requirements for CO<sub>2</sub> reductions from vehicles and the potential solutions – hybrid vehicles and range extended hybrids. Introduction to Real World Driving, WLTC and RDE. Influence of cold start and congested traffic for both SI and diesel vehicles. Comments on the proposed RDE regulations.
- 10.00 Coffee
- 10.15 **Remaining compliant: an insight on changing regulations and the current status of RDE legislation**  
**Piotr Bielaczyc, BOSMAL Automotive Research and Development Institute Ltd., Poland**
- 11.15 **Real world driving in congested traffic: implications for roadside air quality**  
**Professor Gordon Andrews**  
Poor air quality in cities is mainly controlled by the local congested traffic. One of the roadside monitoring sites that exceeds EU air quality standards in NO<sub>x</sub> and PM is in Headingley, Leeds. The emissions from traffic in the congested traffic that passes this roadside air monitoring station is analysed to show the very high emissions in stop/start congested traffic. Congested traffic is not in RDE – why?
- 12.15 Lunch
- 13.00 **Practicality, test success and efficiency challenges of operating a real driving emissions test service**  
**Tom Moakes, Project Engineer, HORIBA MIRA**
- 14.00 **Real world driving emissions with comparison with NEDC and WLTC test cycles for diesel and SI vehicles, including cold start RDE legislation compliance**  
**Piotr Bielaczyc, BOSMAL Automotive Research and Development Institute Ltd., Poland**
- 15.30 Tea
- 15.45 **Efficient Powertrain development for real driving emissions**  
**Simon Williams, Senior Principal Calibration Engineer, MAHLE Powertrain Ltd.**
- 16.45 **Cold-cold start PN and PM emissions from light duty vehicles**  
**Professor David Kittelson, University of Minnesota, USA**  
Cold cold (-8 ± 7 °C) start and idle PM and PN emissions were measured from a small fleet of light-duty vehicles including GDI, PFI, Diesel with DPF. GDI emissions were the highest followed by PFI, Diesel with DPF emissions were nearly indistinguishable from zero.
- 17.30 End of day one
- 17.45 Welcome reception

## **Tuesday 21 May**

### **Real-world driving for SI and diesel vehicles, fuel economy and emissions II**

08.15 Registration and coffee

08.30 **Engine Exhaust Particles in the Atmosphere**

**Professor David Kittelson, University of Minnesota, USA**

Description of measurements of the character of engine exhaust particles as we actually breathe them, on and near roadways. A series of measurements using a mobile emission laboratory conducted for a variety of sponsors over the last ten years will be described.

09.30 **HGV SCR performance in real world driving: catalyst de-light during freewheeling and inefficiency at low temperatures**

**Dr. Hu Li, School of Chemical and Process Engineering, University of Leeds**

10.15 Coffee

10.30 **Real world NO<sub>x</sub> and PN emissions from state of the art Diesel buses**

**Professor David Kittelson, University of Minnesota, USA**

Engines operating in real-world test cycles often emit more than in certification cycles. In this program real world NO<sub>x</sub> emissions from 2013 urban buses were measured and found to exceed certification factors of 4 to 8. However, in response to this problem the emission control system on all 2015 buses were recalibrated by the manufacture leading to real world emission reductions of nearly an order of magnitude without compromising performance.

11.15 **Real driving emissions using fast response analysers**

**Mark Peckham, Cambustion**

Transient engine operation and the resulting short-duration emissions are perhaps the most challenging aspect of RDE. By deploying fast response emissions analysers in-vehicle, the "spikes" of transient emissions can be accurately measured and, more importantly, correlated with  $\lambda$ , spark timing and other engine parameters closely associated with emissions.

12.00 **Euro 3 diesel car in real world congested traffic: major NO<sub>x</sub> problem and a significant cause of high roadside NO<sub>2</sub>. Evidence of DOC de-light in congested traffic.**

**Professor Gordon Andrews**

12.45 Lunch

13.30 **Development of RDE in China**

**Dr Wang Xin, National Laboratory of Automotive Performance and Emissions Test, Beijing Institute of Technology and Visiting Professor, University of Leeds**

15.00 Tea

15.15 **Hybrid Vehicles on Real World Driving**

**Dr Hu Li, School of Chemical and Process Engineering, University of Leeds**

16.15 **The effects of vehicle technology on CO<sub>2</sub> emissions across a range of different drive cycles**

**Ben Leach, BP Formulated Products Technology**

17.30

## **Wednesday 22 May**

### **Fundamentals of SI and diesel gaseous emissions**

08.15 Registration and coffee

08.30 **Diesel and SI engine thermodynamics and turbocharging**

**Professor Gordon Andrews**

Why lean burn gives lower sfc. Turbocharging for leaner combustion and lower sfc, lower PM and NOx

09.15 **Diesel ignition delay and apparent ignition delay in SI engines**  
**Professor Gordon Andrews**

10.00 **The Nissan MK concept with long ignition delay using EGR**  
**Professor Gordon Andrews**

10.30 Coffee

10.45 **Diesel and SI engine processes that influence particulate formation**  
**Professor Gordon Andrews**

The nature of diesel particulates: carbon, unburnt fuel, unburnt lube oil, ash, sulphates plus water. The particulate composition variation with engine power and emissions test cycle.

11.45 **Factors influencing carbon formation in diesel and SI engines**  
**Professor Gordon Andrews**

Combustion processes and engine design factors that influence particulate carbon emissions: lower overall equivalence ratios and hence lower carbon for the same power with TCIC engines. Fuel injector operational parameters that influence mixing and carbon.

12.30 Lunch

13.15 **CO and HC emissions from SI and Diesel Engines**  
**Professor Gordon Andrews**

High CO and HC for premixed SI and diesels. Low CO and HC for central injection DI diesel and SI engine. Premixed combustion gives high CO and HC as in SI engines, and this is a major problem for partially premixed diesels.

14.00 **NOx formation and control in SI and Diesel Engines**  
**Professor Gordon Andrews**

A review of engine NOx formation and reduction techniques. Premixed and diffusion combustion and the two zone model of NOx formation in near stoichiometric zones in a thin region around the fuel jet. Discussion of the link between reducing NOx and increasing particulates. The influence of fuel injection parameters on air/fuel mixing and NOx.

14.45 **EGR for NOx control in SI and diesel engines**  
**Professor Gordon Andrews**

Reduction in peak flame temperature and NOx using EGR, reduced influence of EGR for lower powers and better mixed fuel and air. EGR and reduced sfc in SI and increased sfc in diesels. Problems of achieving EGR in diesels, short and long route. Long route EGR with particle trap. Increase in soot emissions with EGR. Influence of EGR on wear and lube oil contamination. Use of on-line oil cleaning (centrifugal or fine bypass filtration) to control these adverse oil effects. EGR for reduced CO2 in Spark Ignition engines.

15.30 Tea

15.45 **Ultrafine and nanoparticles in diesel, SI and GDI engines**  
**Professor David Kittelson, University of Minnesota, USA**

Mechanisms of formation of these particles in the engine and during sampling and dilution will be described. Particle composition and the roles of solid and semi-volatile particles will be examined. The performance of exhaust filters and the formation of particles downstream of exhaust filters will be examined. The impact of biofuels will also be discussed.

16.45 **Three-way catalyst substrate development**  
**Dr Ameya Joshi, Corning Inc.**

17.30 End of day three

19.00 Course dinner

**Thursday 23 May**

**Particulate and NO<sub>x</sub> aftertreatment with minimum CO<sub>2</sub> penalty**

08.15 Registration and coffee

**08.30 Introduction to emission control by catalysts**

**Dr Claus Goersmann, Johnson Matthey plc**

What are the basic principles of heterogeneous catalysis in automotive applications? Before introducing the different types of emission control catalysts in the following presentations, this presentation shows the common design features of emission control catalysts.

**09.00 Three-way catalysts**

**Dr Claus Goersmann, Johnson Matthey plc**

An introduction to three way catalysts. How do they work? What are the basic underlying principles? Requirements for modern three way catalysts in automotive applications for gasoline and natural gas powered vehicles.

**09.45 Diesel oxidation catalysts**

**Dr Claus Goersmann, Johnson Matthey plc**

An introduction to Diesel oxidation catalysts. What are the key functions and reactions? This presentation looks at DOCs for passive and active (filter regeneration) systems.

10.15 Coffee

**10.30 Diesel particulate filters – overview**

**Dr Ameya Joshi, Corning Inc**

Introduction to wall flow particulate filters. This presentation will cover the choice of materials, and design considerations for superior filtration performance, soot- and ash-loaded pressure drop, and regeneration.

**11.30 The regeneration of particulate filter systems**

**Dr Claus Goersmann, Johnson Matthey plc**

Different regeneration options for particulate filter systems: active regeneration with oxygen and passive regeneration with NO<sub>2</sub>.

12.30 Lunch

**13.15 Particulate trap substrates for GDI engines – gasoline particulate filters (GPF)**

**Dr Ameya Joshi, Corning Inc**

Introduction to gasoline particulate filters and their design considerations. Differences with diesel, and implications for conventional gasoline after-treatment.

**14.15 NO<sub>x</sub> adsorber catalysts**

**Dr Claus Goersmann, Johnson Matthey plc**

An introduction to NO<sub>x</sub> adsorber catalysts and how they are used in an emission control systems. This presentation spans from “traditional” to current and future applications.

15.00 Tea

**15.15 Selective catalytic reduction (SCR)**

**Dr Claus Goersmann, Johnson Matthey plc**

An introduction to the different types of selective catalytic reduction (HC and NH<sub>3</sub> based) and emission control. The focus of this presentation is on ammonia based SCR and the different types of catalysts applied in today's NO<sub>x</sub> control systems.

**16.15 SNCR: SCR - urea mixing and control; influence on PM**

**Professor Gordon Andrews**

SNCR reduces NO<sub>x</sub> without a catalyst: principles and application are reviewed. Open loop and closed loop control of urea addition in transient cycles. Use of non-optimum Urea/NO<sub>x</sub> ratios in transient cycles to avoid ammonia slippage. Mixing uniformity of urea and exhaust.

The particulate (SOF and carbon) reduction in modern SCR systems (up to 74% demonstrated) with no trapping function.

17.00 **Integrated Systems**  
**Dr Claus Goersmann, Johnson Matthey plc**  
Summary

17.30 End of day four

## **Friday 24 May**

### **Diesel fuel injection and engine design trends for low NO<sub>x</sub>, PM and CO<sub>2</sub> emissions**

08.15 Registration and coffee

08.30 **Common rail fuel injection systems**  
**Dan Mellors, Delphi Technologies**  
Traditional Fuel Injection Systems will be presented: high pressure rotary pumps and pump-line-nozzle systems. Their drawbacks will be discussed with regard to current/future requirements. Unit Injector and Common Rail Fuel Injections Systems will be explained and their specific advantages to conventional systems highlighted. The usage of control strategies to enhance the performance of the fuel injection equipment will be discussed. Future requirements for common rail systems will be presented.

10.00 Coffee

10.15 **Turbocharging for low emission heavy duty diesels**  
**Parasharan Ananthakrishnan, Cummins Turbo Technologies Ltd**  
A review of current turbocharging technology and the interaction of the turbocharger with Heavy Duty diesel engine emissions reducing strategies.

11.30 **Emissions control strategy on large heavy duty engines**  
**Dr Esmail R Karimi, Niro Engineering Ltd**

12.30 Lunch

13.15 **Cold start and implication for Real World Emissions in urban driving**  
**Professor Gordon Andrews**  
Water and lube oil warm up – CO<sub>2</sub> implications. TWC, DOC and deNO<sub>x</sub> catalyst light off problems and techniques for rapid catalyst heat up. The same technique should be used for LNT rich regeneration spike and particle trap carbon burn out. Cold start into real urban traffic.

14.45 **Review of RCCI and HCCI**  
**Professor Gordon Andrews**

15.45 **Lube oil review for SI and diesel emissions**  
**Professor Gordon Andrews**

16.30 Tea and end of course