Monday 21 May
Real-world driving for SI and diesel vehicles, fuel economy and emissions

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 CO₂ 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 NOx and PM is in Headingley, Leeds. The emissions from traffic in the congested traffic that passes this roadside air monitoring stating 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 drive emissions
        Simon Williams, Senior Principal Calibration Engineer, MAHLE Powertrain Ltd.

16.45  Cold start PM and PN emissions from PFI and GDI gasoline 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 22 May

AM – mainly HDD and bus real drive emissions

08.15 Registration and coffee

08.30 Engine exhaust particles in the atmosphere. Measurement of HDD vehicle exhausts on the highway using a mobile emissions laboratory
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 HDD SCR performance in real world driving: evidence of catalyst de-light during freewheeling
Dr. Hu Li, School of Chemical and Process Engineering, University of Leeds

10.15 Coffee

10.30 Real world NOx emissions from state of the art diesel buses. Recalibration of the bus engines to reduce the RDE emissions to those similar to the legislated test cycle.
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 NOx 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
Dr. Mark Peckham, Director, 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 λ, spark timing and other engine parameters closely associated with emissions.

12.00 Euro 3 diesel car in real world congested traffic: major NOx problem and a significant cause of high roadside NO2. Evidence of DOC de-light in congested traffic.
Professor Gordon Andrews

12.45 Lunch

PM – Fundamentals of diesel and SI engines – all Professor Gordon Andrews

13.30 Diesel and SI engine thermodynamics and turbocharging
Why lean burn gives lower sfc. Turbocharging for leaner combustion and lower sfc, lower PM and NOx

14.15 Diesel ignition delay and apparent ignition delay in SI engines

15.00 Coffee

15.15 The Nissan MK concept with long ignition delay using EGR

16.00 Diesel and SI engine processes that influence particulate formation
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.

17.00 Factors influencing carbon formation in diesel and SI engines
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.

17.45 End of day two
Wednesday 23 May
Fundamentals of SI and diesel gaseous emissions

08.15 Registration and coffee

08.30 **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.

10.00 Coffee

10.15 **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.

11.15 **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 rout. 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.

12.30 Lunch

13.15 **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.

14.15 **The effects of vehicle technology on CO2 emissions across a range of different drive cycles**
**Ben Leach, BP Formulated Products Technology**

15.30 Tea

15.45 **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.

16.30 **Three-way catalyst substrate development**
**Dr Cameron Tanner, Corning Inc.**

17.15 End of day three

19.00 Course dinner
Thursday 24 May
Particulate and NOx aftertreatment with minimum CO² penalty

08.15 Registration and coffee

08.30 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.

09.30 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 Cameron Tanner, 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 NO₂.

12.30 Lunch

13.15 Particulate trap substrates for GDI engines – gasoline particulate filters (GPF)
Dr Cameron Tanner, Corning Inc
Introduction to gasoline particulate filters and their design considerations. Differences with diesel, and implications for conventional gasoline after-treatment.

14.15 NOx adsorber catalysts
Dr Claus Goersmann, Johnson Matthey plc
An introduction to NOx 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 NH₃ based) and emission control. The focus of this presentation is on ammonia based SCR and the different types of catalysts applied in today’s NOx control systems.

16.15 SNCR: SCR - urea mixing and control; influence on PM
Professor Gordon Andrews
SNCR reduces NOx 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/NOx 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 25 May
Diesel fuel injection and engine design trends for low NOx, PM and CO² emissions

08.15 Registration and coffee

08.30 Common rail fuel injection systems
Simon Tullis, 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
Vishal Seeburrun, 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 – CO2 implications. TWC, DOC and deNOx 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

16.00 Tea and end of course