Faculty of Engineering

UNIVERSITY OF LEEDS

Engine Emissions Measurement

Monday 21 – Friday 25 June 2010

Course Director:
Professor Gordon Andrews
Energy and Resources Research Institute
School of Process, Environmental and Materials Engineering

idgtE

HORIBA
Automotive Test Systems

Please pass this leaflet to a colleague if this course is not relevant to you

Image courtesy of Powertrain and Vehicle Research Centre, Department of Mechanical Engineering, University of Bath

ENGINE EMISSIONS MEASUREMENT
Monday 21 – Friday 25 June 2010

COURSE AIMS

A specialist course, with extensive participation by lecturers from Horiba Instruments that is aimed at teaching the latest developments in automotive and industrial engine emissions measurement procedures. The course is directed at both emissions legislation compliance and at engine and catalyst development for low emissions. Passenger car emissions legislation measurement requirements are fully detailed for ultra-low emission SI and diesel vehicles. Heavy duty diesel emissions legislation measurement methods for on-road and off-road engine uses are fully described, including the latest European proposals for measurement of particle number as well as mass. The specialist areas of time resolved emissions in test cycles for emissions control engine development is also covered in detail. The accurate determination of CO_2 emissions and fuel consumption from the legislated test cycles is a major theme of the course. The course also covers the fast growing area of in-vehicle emissions measurement for real world driving emissions measurement. Several areas are covered that are currently not regulated in the Europe but are in the USA and may be regulated in future in Europe. This includes VOC speciation for ozone forming potential evaluation as well as air toxics and PAH speciation of diesel particulates for carcinogenic toxic emissions evaluations.

The first day explains the function of heated on-line gas analysis systems for CO_2, CO, O_2, UHC, NO_x and SO_x measurements from gas turbine, diesel and spark ignition engines using liquid and gaseous fuels. Computer processing of gas analysis measurements to derive air/fuel ratios, combustion efficiency, temperature and various pollution parameters will be discussed.

The second day deals with hot gas sampling, CVS, fast response analysis and chassis dynamometer regulated emissions test procedures, including measurement procedures for ultra low emissions gasoline and diesel regulations. Also included is legislated accurate CO_2 emissions measurement. Methods of measuring transient emissions and the gas analysis requirements of fuel cell vehicles are also reviewed. This day is entirely taught by Horiba Instruments.

On the third day the techniques for real world in-vehicle emissions measurement are discussed. The techniques for the speciation of hydrocarbon emissions using GC, FTIR and mass spectrometry (MS) are described together with their applications in gasoline engine catalyst and engine control system development. The last part of the day introduces the subject of particulate measurement.

The fourth day is specific to legislated heavy duty diesel engine particulate emissions measurement. Transient particle mass analysis techniques are detailed (TEOM) as well as on line analysis techniques for particulate mass and volatile fraction. Laboratory techniques are reviewed for particulate analysis for the determination of the VOF/carbon split as well as on-line techniques for their rapid determination.

The last day covers spark ignition and diesel engine particle size analysis and related measurement problems. It also covers techniques of the fuel/lube split of the VOF and the related problem of transient lubricating oil consumption measurement. The last part of the day deals with particulate and fuel PAH analysis using GC-MS and related solvent extraction techniques.

INTENDED AUDIENCE

The course is aimed at engine emissions measurement personnel and their supervisors. It is particular suitable for newly appointed staff in these areas, who need to learn quickly about emission measurement methods. It is also relevant to operators of diesel and gas turbine electric generation equipment who have to make emissions measurements, perhaps for the first time, under the Environmental Protection Act. The course covers both existing instrumentation and new developments in emissions measurement techniques and instruments, and will be of interest to those who wish to learn about the latest developments in emissions measurement technology.

It will also be relevant to engine gas analysis system designers. It will be of particular relevance to those who have recently been made responsible for engine emissions measurement and who need information on the design and operation of these systems. It is also suitable for those involved in data processing of emissions measurements. Applications will be discussed in spark ignition, diesel and gas turbine engines.

Monday 21 June 2010 – GAS ANALYSIS: GASOLINE REGULATED EMISSIONS

08.30 Registration and coffee

09.00 **Introduction to emissions regulations and measurement requirements**
Professor Gordon Andrews, Energy and Resources Research Institute, University of Leeds
Brief introduction to emissions formation, emission regulations, test cycles and the reasons for interest in non-regulated emissions.

11.00 Coffee

11.15 **Legislative chassis dynamometer test procedures**
Rick Spurgeon, Horiba Instruments Ltd
Evolution of Chassis Dynamometer regulatory Emission Test requirements. Covering Passenger Cars, Light Commercial Vehicles & Motorcycles, including fundamental equipment profiles and techniques. Calculation of test cycle mass emissions from measured data. Review of current test limits and programmed test limit reductions where applicable. Includes review of forthcoming Euro 6 amendment for Light Duty Vehicles, and an outline of EU strategy for reduction of Passenger Car CO_2 emissions.

12.30 Lunch

13.15 **Requirements and principles of exhaust gas analysis instruments**
Professor Gordon Andrews, Energy and Resources Research Institute, University of Leeds
Basics of pollutant measurement, pollutants to be measured, on line exhaust pipe sample emission measurement systems.

14.30 **Non-dispersive infra-red exhaust emissions analysis**
Rick Spurgeon, Horiba Instruments Ltd
Single or multi-channel gas analysis systems, instrument fundamentals, configuration, minimum concentrations, specifications and applications.

15.30 Tea

15.45 **Flame ionisation detection of total hydrocarbons and chemiluminescent analysis of oxides of nitrogen**
Rick Spurgeon, Horiba Instruments Ltd
Instrument fundamentals, configuration, minimum concentrations, specifications and applications. Type of flame, sensitivity to hydrocarbon type, non-methane hydrocarbons, influence of sample flow rate, NOx reaction cell pressure effects, NO_2 to NO converters.

16.45 **Computer processing of gas analysis measurement**
Professor Gordon Andrews, Energy and Resources Research Institute, University of Leeds
Examples of the calculation of A/F, combustion efficiency and mass emissions from wet and dry gas volumetric exhaust concentrations using practical engine emissions test results. Sensitivity to fuel hydrogen and oxygen content and calculation of A/F from O2 or CO_2 measurement, including biofuels.

17.30 End of day one

Tuesday 22 June 2010 – REGULATED EMISSIONS MEASUREMENT PROCEDURES AND TRANSIENT EMISSIONS

08.30 Registration and coffee

08.45 **Heated sample handling systems for exhaust emissions measurement**
Les Hill, Horiba Instruments Ltd
Description of system hardware, high temperature pumps and valves, heated sample lines, heated filters, integrated hot sampling systems.

09.45 **Integrated gas analysis systems part 1: engine cell applications**
Rick Spurgeon, Horiba Instruments Ltd
Integration and configuration of test equipment for Engine Test Cell applications including data acquisition and control. Selection of test dynamometer and test cell computer requirements. Test cell operations and principal system specifications required. Data handling and System Control functions for steady state or transient test procedures. Introduction to Fast Analysis exhaust analysis techniques and review of equipment / test data.

10.45 Coffee

11.00 **Constant volume sampling (CVS) systems for light duty vehicles**
Les Hill, Horiba Instruments Ltd
The fundamental concept and legislative requirements for the design and operation of CVS emissions systems for passenger car application.

12.15 **Integrated gas analysis systems part 2: chassis cell applications**
Rick Spurgeon, Horiba Instruments Ltd
Configuration of Chassis Test Cell equipment profiles in terms of dynamometer and emissions measurement equipment. Comparison of continuous versus bag test techniques, and diagnostic evaluation of generated test data. Test Cell computer functions, operating methods and applications. Calculation of overall test mass emissions. Countermeasures and procedural precautions to maximise quality of measured emission test data.

13.00 Lunch

14.00 **Enhanced CVS and gas analysis for gasoline SULEV & EU Stage 5 Legislation**
Les Hill, Horiba Instruments Ltd
The enhancements required for CVS and analytical systems for the measurement and verification of emissions from low emission gasoline and alternative fuel vehicles including hybrid electric powertrains

15.00 Tea

15.15 **Alternatives to CVS for measuring vehicle exhaust mass emissions**
Les Hill, Horiba Instruments Ltd
Methods of Direct Exhaust Flow Rate Measurement. Description of Bag Mini-Diluter method for SULEV measurement. Review of Direct Modal Mass Measurement Method.

16.15 **Emissions measurement procedures for hybrid vehicles**
Les Hill, Horiba Instruments Ltd

17.15 End of day two

19.00 Course dinner

A full programme including detailed lecture descriptions can be viewed online at www.engineering.leeds.ac.uk/cpd

Wednesday 23 June 2010 – NON-REGULATED GASOLINE EMISSIONS

08.15 Registration and coffee

08.30 **On-road in-vehicle direct exhaust sampling for real world driving emissions monitoring**
Professor Gordon Andrews, Energy and Resources Research Institute, University of Leeds
On road emission measurement using direct exhaust sampling into a bag via a condenser with proportional sampling using the exhaust back pressure to drive the gas sample.

10.15 Coffee

10.30 **On-road in-vehicle emissions analysis**
Les Hill, Horiba Instruments Ltd
Description of requirements for 'Field Measurement Systems' for US and EU. On-road and real world mass emission measurements using a purpose built system with HFID, CLA, NDIR and Exhaust Flow Meter. Correlations with CVS method and a mapped mass emission measurement in town will be shown.

11.30 **HC speciation and carbonyl analysis for determination of reactivity adjusted NMOG, including some fuel and engine effects.**
Professor Gordon Andrews, Energy and Resources Research Institute, University of Leeds
The methods used for reactivity adjustment factors (RAF) determination, the reasoning behind RAF, and general trends of fuel and engine effects.

12.30 Lunch

13.15 **On-line analysis of non-regulated pollutants using FTIR, mass spectrometry and other techniques. H2 analysis and fuel cell gas analysis requirements**
Les Hill, Horiba Instruments Ltd
Methodologies of regulated and non-regulated emission species from engine exhaust using FTIR, mass spectrometry and other techniques

14.15 **Experience in using FTIR and mass spectrometry instrumentation**
Dr Phil Price, Powertrain Testing Europe, Ford Motor Company
Use of on-line speciation techniques (MS and FTIR) as tools for powertrain development (and extras)

15.15 Tea

15.30 **Diesel particulate sampling**
Professor Gordon Andrews, Energy and Resources Research Institute, University of Leeds
Sample collection techniques, optical techniques, Bosch smoke

16.45 **Continuous PM measurement techniques**
Les Hill, Horiba Instruments Ltd
Several techniques for the real time measurement of PM will be discussed, especially that of the differential HFID technique for the measurement of soot and SOF. Correlation with the conventional method and some application data will be shown.

17.30 End of day three

Thursday 24 June 2010 – DIESEL PARTICULATE ANALYSIS

08.15 Registration and coffee

08.30 **Dilution tunnels**
Professor Gordon Andrews, Energy and Resources Research Institute, University of Leeds
Dilution tunnels and the influence of operating conditions, changes in particulate composition during cooling along an exhaust pipe.

10.00 Coffee

10.15 **CVS systems for heavy duty diesel measurement**
Les Hill, Horiba Instruments Ltd
The legislative requirements for the design and operation of CVS emissions systems for heavy duty diesel applications.

11.30 **Legislative engine dynamometer test procedures**
Rick Spurgeon, Horiba Instruments Ltd
Evolution of Engine Dynamometer regulatory Emission Test requirements. Covering On-Road Heavy Duty and Non-Road Mobile Machinery categories, including fundamental equipment profiles and techniques. Calculation of test cycle mass emissions from measured data. Review of current test limits and programmed test limit reductions where applicable. Includes a review of the forthcoming Euro 6 amendment for On-Road Heavy Duty Vehicles, and an outline of phased introductions for Non-Road Mobile Machinery categories.

12.15 Lunch

13.15 **Ultra low emission diesel measurements**
Les Hill, Horiba Instruments Ltd
Includes a review of EPA 1065 methods and GRPE-PMP specifications for low PM mass measurement and solid particle number measurement. Description of compliant systems.

14.45 **EPA1065 regulations**
Rick Spurgeon, Horiba Instruments Ltd

15.30 Tea

15.45 **Design principles for partial flow dilution systems**
Les Hill, Horiba Instruments Ltd
Dilution tunnels design using part of the exhaust gas flow, double dilution systems, micro dilution tunnels using a very small proportion of exhaust gas sample flow, smart samplers.

16.45 **Transient particulate analysis using TEOM**
Les Hill, Horiba Instruments Ltd
The Tapered Element Oscillating Microbalance technique for on-line transient analysis of diesel particulates from dilution tunnel samples.

17.30 **On-line PM analysis and speciation techniques**
Les Hill, Horiba Instruments Ltd
Description of particulate mass measurement and component speciation using gas analysis.

18.00 End of day four

Friday 25 June 2010 – ADVANCED ANALYTICAL TECHNIQUES FOR EMISSIONS MEASUREMENT

08.15 Registration and coffee

08.30 **Particle size analysis and optical properties of particulates**
Professor Gordon Andrews, Energy and Resources Research Institute, University of Leeds
Techniques for the measurement of particle size (SMPS and ELPI) in soot aerosols and diesel exhaust gases and their optical properties, including the influence of absorbed hydrocarbons.

10.00 Coffee

10.15 **Measurement problems for diesel particle size number and mass distribution**
Professor Gordon Andrews, Energy and Resources Research Institute, University of Leeds
Influence of dilution ratio on particle size and in double dilution system the influence of the primary dilution ratio. Fuel sulphur influences. Size distribution bias for the ELPI. Problem of conversion from number to mass distribution.

11.45 **Transient HC, NO_x, CO, CO_2 and particle measurement in IC engines**
Dr Mark Peckham, Cambustion Ltd
Description of fast FID, CLD, NDIR and Particulate Spectrometer instruments. Application to raw exhaust gas measurement.

12.30 Lunch

13.30 **Particle SOF and fuel/lube analysis**
Professor Gordon Andrews, Energy and Resources Research Institute, University of Leeds
SOF-GC, SOF-pyroGC, radio tracer and TGA methods of lube oil particulate emissions.

14.00 **Transient lube oil consumption measurement during emission test cycles**
Professor Gordon Andrews, Energy and Resources Research Institute, University of Leeds
Radio tracer, SO_2 and calcium tracer techniques for lube oil consumption measurement during a particulate measurement test. Lube oil combustion efficiency determination.

14.30 **Particulate PAH analysis**
Professor Paul Williams, Energy and Resources Research Institute, University of Leeds
A review of analytical methodologies for the polycyclic hydrocarbon content of diesel particulates, covering extraction, separation and final analysis techniques.

15.30 Tea

15.45 **GC – MS in the analysis of PAH**
Professor Keith Bartle, Department of Chemistry, University of Leeds
Separation by GC followed by identification by mass spectrometry in PAH analysis.

16.30 **Coupled chromatographic methods in the analysis of PAH and their derivatives**
Professor Keith Bartle, Department of Chemistry, University of Leeds
Pre-separation by LC followed by on-line GC in PAH analysis. Methods for the analysis of oxygen, sulphur and nitro containing derivatives of PAH by LC – GC, LC – GC – MS, and GC – AED. Comprehensive GC x GC and GC x GC-MS.

17.00 End of day five and course

To receive an electronic registration form email us at: cpd@engineering.leeds.ac.uk

ADMINISTRATIVE DETAILS

VENUE
The venue for the course will be Weetwood Hall Conference Centre and Hotel which offers first-class hotel facilities, a business centre and ample parking facilities. Weetwood Hall is the largest and most flexible conference centre and hotel in the North of England.

Weetwood Hall Hotel is ideally situated 15 minutes north of the centre of Leeds in wooded grounds at the junction of the Otley Road and the outer ring road. It is just 15 minutes from Leeds Bradford International Airport and a short distance from the A1, M1, M606, M621 and M62 motorways.

Further details can be found at www.weetwood.co.uk

ACCOMMODATION
Bed and breakfast accommodation at Weetwood Hall Hotel can be booked on behalf of delegates if required and this will be added to your invoice. All rooms are non-smoking and have en-suite facilities. Residents also have free access to the David Lloyd Leisure Centre which is a short distance away.

We have negotiated the following special rates per night:

Friday – Sunday evening, bed and breakfast	**£ 62**
Monday – Thursday evening, bed and breakfast	**£ 87**

Delegates are responsible for their own evening meals except on Tuesday 22 June when the course dinner is included.

A list of alternative hotels is available on request.

COURSE DINNER
The course dinner will be held at a Leeds city centre restaurant and is included in the course fee. This will take place on Tuesday evening and transport from and to Weetwood Hall Hotel is provided. The dress code is smart casual. If you would like to attend please indicate on the registration form.

COURSE FEES
The following course fees include the cost of tuition, course notes, lunches and light refreshments for the day(s) of attendance:

£1485 Full five days
£370 Any one day

TERMS AND CONDITIONS
Payment should accompany your registration form unless you have requested an invoice to be sent to you. Please note, registrations received without a supporting purchase order document cannot be processed. The course fee is exempt from VAT and payment can be made by bank transfer, credit card or cheque made payable to the 'University of Leeds'. Please note, due to University policy we can only accept credit card details over the telephone. Unfortunately we are unable to accept payment by American Express. Terms of payment are 30 days from date of invoice. Fees must be paid in full no later than 10 working days before the course commences. Failure to pay may result in attendance being refused.

Registrations are accepted on the understanding that the printed programme is given in good faith but may have to be re-scheduled or the speakers changed for reasons outside our control. The University of Leeds reserves the right to cancel or postpone the course, in which case fees will be refunded in full. In the event of cancellation, the University will not be held liable for delegates travel or accommodation expenses. Where a delegate wishes to cancel a registration, written cancellations received up to 10 working days before the course will be subject to an administrative charge of 20% of the total remittance. After this date the full fee is chargeable and no refunds will be made, this also applies for non-attendance but copies of the course documents will be sent. Substitutions may be made at any time.

REGISTRATION AND ENQUIRIES
To register please complete and return the registration form by email, post or fax. For enquiries please contact:

Rachael Lawson, CPD Course and Events Co-ordinator,
CPD Unit, Faculty of Engineering,
c/o School of Civil Engineering, Room 209,
University of Leeds,
LEEDS, LS2 9JT, UK.
T: + 44 (0) 113 343 8104
F: + 44 (0) 113 343 2511
E: cpd@engineering.leeds.ac.uk W: www.engineering.leeds.ac.uk/cpd

Potential delegates who have any special requirements should contact the above as soon as possible.

CPD SHORT COURSES ENQUIRY FORM:
To receive regular updates and details of our future courses please tick the relevant courses below and insert details.

AUTOMOTIVE ENGINEERING
- ❑ Diesel Particulates and NO_x Emissions 17 – 21 May 2010
- ❑ Engine Emissions Measurement 21 – 25 June 2010
- ❑ Diesel Particulates and NOx Emissions (USA) November 2010
- ❑ Spark Ignition Engine Combustion 17– 21 January 2011

WASTE AND ENVIRONMENT
- ❑ Energy from Biomass Combustion
- ❑ Industrial Air Pollution Monitoring
- ❑ Thermal Treatment of Municipal Waste

POWER AND PROCESS ENGINEERING
- ❑ Energy from Biomass Combustion
- ❑ Chemical Plant Commissioning
- ❑ Combustion in Boilers and Furnaces
- ❑ Ultra Low NO_x Gas Turbine Combustion

FIRE ENGINEERING
- ❑ Fire Dynamics and Modelling
- ❑ Fire and Explosion Investigation
- ❑ Fire Safety Design
- ❑ Flame Retardancy and Flammability of Polymers and Textiles
- ❑ Gas, Vapour and Dust Explosion Hazards, Protection, Mitigation and Prediction
- ❑ Fire Safety Management and Risk Assessment*
- ❑ Economics of Fire Protection*

**Distance learning programmes*

MSc COURSES
- ❑ MSc in Combustion and Energy
- ❑ MSc in Energy and Environment
- ❑ MSc in Fire and Explosion Engineering

(Prof / Dr /Mr / Mrs / Miss / Ms) please select

First name: .....

Surname: .....

Position held: .....

Organisation: .....

Address: .....

.....

..... Postcode: .....

T: ..... F: .....

E: .....

Please send completed form to:
Rachael Lawson, CPD Course and Events Co-ordinator,
CPD Unit, Faculty of Engineering, c/o School of Civil Engineering, Room 209,
University of Leeds, LEEDS, LS2 9JT, UK.
T: + 44 (0) 113 343 8104 F: + 44 (0) 113 343 2511
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REGISTRATION FORM
ENGINEERING EMISSIONS MEASUREMENT Monday 21 – Friday 25 June 2010

I wish to register on the above course (*please tick and insert details*).

COURSE FEES	**Cost**
❑ FULL FIVE DAYS or a combination of	**£1485**
❑ Monday 21 June 2010	**£370**
❑ Tuesday 22 June 2010	**£370**
❑ Wednesday 23 June 2010	**£370**
❑ Thursday 24 June 2010	**£370**
❑ Friday 25 June 2010	**£370**
Total course fee	**£** .....

COURSE DINNER
I would like to attend the course dinner on Tuesday 22 June 2010 ❑ YES ❑ NO

ACCOMMODATION
Please book the following en-suite bed and breakfast accommodation which I understand will be added to the invoice and paid to the University of Leeds

❑ Sunday 20 June 2010	£62
❑ Monday 21 June 2010	£87
❑ Tuesday 22 June 2010	£87
❑ Wednesday 23 June 2010	£87
❑ Thursday 24 June 2010	£87
❑ Friday 25 June 2010	£62
Total accomodation fee	**£** .....
Total payable to the University of Leeds	**£** .....

DELEGATE (Prof / Dr / Mr / Mrs / Miss / Ms) please select

Surname: ..... Initials: .....

First name for badge: .....

Position held: .....

Organisation: .....

Address: .....

.....

..... Postcode: .....

T: ..... F: .....

E: .....

Special dietary requirements: .....

PAYMENT DETAILS (Please tick box indicating payment method)

- ❑ I enclose a cheque* for £..... made payable to 'The University of Leeds' **Please note that cheques should accompany your registration form and should be made payable in pounds sterling and drawn on a UK bank.*
- ❑ Please invoice my organisation. I attach an official purchase order document to accompany this registration. *Please note, registrations without a supporting purchase order document cannot be processed.*
- ❑ I wish to pay by credit card, please contact me for my card details.

In sending this registration, I agree to the Terms and Conditions stated.

Please send completed registration form to: Rachael Lawson,
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