

## Trends in automotive emissions, fuels, lubricants, legislation and test methods – a global view, with a focus on the EU & US – Summary of the 5<sup>th</sup> International Exhaust Emissions Symposium (IEES)

*The field of vehicular exhaust emissions is experiencing wide-ranging and rapid changes. Air quality is very high on the political agenda and pressure remains to limit and reduce greenhouse gas emissions from the road transport sector. In addition to limits being increasingly stringent, the list of parameters subject to legal limits are slowly expanding – and, most importantly, these limits must be met under a wide wide range of conditions. A range of strategies are available to overcome these difficulties, which was explored during the 5<sup>th</sup> International Exhaust Emissions Symposium (IEES) hosted at BOSMAL in May 2016. This paper reports and summarises the topics of the 5<sup>th</sup> IEES and attempts a synthesis on the current status of the field and what the coming years may hold for the automotive and fuel industries and other allied fields.*

Key words: *exhaust emissions, emissions standard, RDE, WLTP, WLTC, biofuel, exhaust aftertreatment systems, fuel, lubricant*

### Introduction

One of the most important factors influencing socio-economic development and improvement of quality of life is the development of means of transportation and energy sources (fuels) – first of all with mineral liquid fuels, but also with alternative fuels. However, such development causes negative effects like air pollution from gaseous emissions and particulate matter originating from engines (but also from other vehicle systems). The influence of those harmful factors remains significant.

The problem of reducing greenhouse gas emissions (especially CO<sub>2</sub>), emitted by road vehicles is very high on the political agenda, limits for particulate emissions are also being tightened; in the USA particulate mass (PM) and in Europe, especially the number of particles (PN), emissions of which will be limited for spark ignition engines with direct injection (DI SI).

These compounds are regarded as pollutants with far-reaching negative impacts on the environment. In the case of NO<sub>x</sub>, the problem is wide deviations in the results of laboratory measurements and on-road measurements using PEMS systems. A potential danger is also the emission of harmful compounds which are not yet subject to legal limits. The issue of harmful emissions (and fuel consumption, which is connected also with global demand for fuel and energy security) occurring in real traffic conditions is a priority of the automotive sector, especially in the European Union and the United States. It is also a subject of public debate with the participation of international organizations that deal with emissions and emissions testing (e.g. the ICCT).

The response of legislative institutions dealing with this subject has been the introduction of many legal acts determining the permissible emissions of vehicles and methods for their measurement, some imposing increasingly stringent limits on emissions of various harmful compounds, a number of other mandatory guidelines, incentive plans for reducing fuel consumption and the introduction of low-carbon fuels and alternative fuels. Now, in light of revelations that emis-

sions of certain compounds measured in real conditions are poorly reflected in laboratory tests (especially NO<sub>x</sub>), measurement methods will change. This concerns both laboratory methods (e.g. the new test procedures prepared by the UN-ECE – WLTP/ GTR15; or the US EPA – US 1065/1066), as well as emissions and fuel consumption measurements under real-world conditions (real driving emissions, RDE). RDE measurements have turned out to be so important that that test method is to become an integral part of the test procedure

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Final Programme  
Trends in automotive emissions, fuels, lubricants, legislation and test methods - a global view, with a focus on the EU & US

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Front page of symposium programme



Bielsko-Biala, Poland


## 5<sup>th</sup> International Exhaust Emissions Symposium 19-20 May 2016

### Final Programme

**Thursday, 19 May 2016**

- 08:00 - 09:00 - Registration
- 09:00 - 09:10 - Welcome and Opening Address
- 09:00 - 09:10 - Prof. Jerzy Merkisz (PTNSS), Dr. Arkadiusz Stojek (BOSMAL) & Dr. Piotr Bielaczyc (International Organising Committee) [10]
- 09:10 - 09:40 - Session 1: The Automotive Emissions Landscape in the US and the EU  
Chairs: Wolfgang Thiel (TRT, Germany) & Piotr Bielaczyc (BOSMAL, Poland)
- 09:10 - 09:40 - Dr. Piotr Bielaczyc (BOSMAL, Poland) - Which strategy is better for emissions control - the EU or the US? - an introduction to the question [30]
- 09:40 - 10:20 - Dr. Vicente Franco (The ICCT Europe, Germany) - A comparison of emission standard design and enforcement approaches in the EU and US [40]
- 10:20 - 10:50 - Giovanni D'Urbanò, (FOEN, Switzerland) - Swiss approach and experience in controlling air pollution emissions from internal combustion engines and gas turbines [30]
- 10:50 - 11:30 - Coffee break, poster presentation [40]
- 11:30 - 12:00 - Kurt Engeljehring (AVL, Austria) - Global emission regulations and testing methods on the local differences [30]
- 12:00 - 12:30 - Dr. Miriam E Gerlofs-Nijland (National Institute for Public Health and the Environment, the Netherlands) - Adverse health effects of traffic-derived emissions - the impact of biofuel [30]
- 12:30 - 13:30 - Lunch, poster presentation [50]
- 13:30 - 14:15 - Session 2: Emissions Reduction Technologies and Strategies  
Chairs: Tim Johnson (Corning, USA) & Piotr Bielaczyc (BOSMAL, Poland)
- 13:30 - 14:15 - Keynote: Dr. Timothy Johnson (Corning, USA) - Directions in vehicular emissions and efficiency [45]
- 14:15 - 14:45 - Mike Douba (Center for Transportation Research, Argonne National Laboratory, USA) - Testing PHEVs and BEVs to determine expectations in reduced emissions and fuel usage [30]
- 14:45 - 15:05 - Prof. Federico Millo (Polito, Italy) - Modelling of LNT and SCR on filter for passenger car applications [20]
- 15:05 - 15:45 - Coffee break, poster presentation [40]
- 15:45 - 16:05 - Dr. Gerhard Schopp (Continental, Germany) - Calibration and validation of engine management systems with respect to actual and future exhaust emission legislations [20]
- 16:05 - 16:25 - Dr. Claus Goersmann (Johnson-Matthey, UK) - Low carbon transport 2050: Powertrain options [20]
- 16:25 - 16:55 - Session 3: Real Driving Emissions  
Chairs: Wolfgang Thiel (TRT, Germany) & Vicente Franco (ICCT Europe, Germany)
- 16:25 - 16:55 - Helge Schmidt (TUV, Germany) - Real Driving Emissions - status of discussion and practical experience [30]
- 16:55 - 17:10 - Prof. Gordon Andrews (University of Leeds, UK) - Real world SI vehicle emissions in low speed congested traffic [15]
- 17:10 - 17:25 - Prof. Gordon Andrews (University of Leeds, UK) - Real world emissions performance of a HDD truck with urea SCR NO<sub>x</sub> control [15]
- 17:25 - 17:45 - Prof. Jerzy Merkisz (BOSMAL/Poznan University of Technology, Poland) - Investigations on exhaust emission from off-road vehicles and rail vehicles using PEMS [20]
- 17:45 - 18:00 - Michael Heuser (Sensors Europe GmbH, Germany) - Advances in PN PEMS [15]
- 20:00 - Symposium Dinner and Musical Soiree at Palac Kotulskich

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## 5<sup>th</sup> International Exhaust Emissions Symposium 19-20 May 2016

**Friday, 20 May 2016**

- 09:00 - 09:30 - Session 4: Particle Matter Emissions and their Measurement and Control  
Chairs: Wolfgang Thiel (TRT, Germany) & Piotr Bielaczyc (BOSMAL, Poland)
- 09:00 - 09:30 - Prof. William Northrop (University of Minnesota, USA) - Semi-volatile particulate matter from low temperature Diesel combustion using conventional and alternative fuels [30]
- 09:30 - 10:00 - William Silvis (AVL Inc., USA) - Making sense of PM measurement at 1 mg/mi, 6E11 #/km [30]
- 10:00 - 10:20 - Dr. Topi Ronkko, Jenni Alanen, Erika Saukko, Kati Lehtoranta, Timo Murtonen, Hilka Timonen, Risto Hillama, Dr. Panu Karjalainen, Heino Kuuluvainen, Juha Harra, Prof. Jorma Keskinen (1: Tampere University of Technology, Finland; 2: VTT Technical Research Centre of Finland; 3: Finnish Meteorological Institute) - Nanoparticles in natural gas engine exhaust [20]
- 10:20 - 10:35 - Dr. Jonna Kannisto, Dr. Mikko Moisio, Ville Niemela, Henna Isherwood (Dekati, Finland) - Gravimetric PM filter results can be improved with integrated real time particle concentration measurement [15]
- 10:35 - 11:15 - Coffee break, poster presentation [40]
- 11:15 - 11:45 - Session 5: Fuel and Lubricant Development in Light of Emissions Requirements and Industry Trends  
Chairs: Amanda Lea-Langton (University of Manchester, UK) & Sabina Kawczak (PKN Orlen, Poland)
- 11:15 - 11:45 - Keynote: Dr. Thomas Wallner (Center for Transportation Research, Argonne National Laboratory, USA) - Co-optimization of fuels and engines [30]
- 11:45 - 12:05 - Thomas Hartmann, Uwe Lutz, Mathias Lohman, Marc Walter, (BASF SE, Germany) - Impact of soot formation on lubricant ageing in DISI engines [20]
- 12:05 - 12:25 - Knut Skardalsmo (Skardalsmo Fuel Consulting, Norway) - Bridging the gap to the hydrogen economy [20]
- 12:25 - 12:45 - Dr. Heather Hamje (CONCAWE, Belgium) - Studies of fuel effects in modern Diesel passenger cars [20]
- 12:45 - 13:00 - Prof. Miroslaw Wyszynski (University of Birmingham, UK) - Gaseous and particulate emissions from a diesel fuel emulsion containing up to 20% of pyrolysis oil obtained from woody biomass [15]
- 13:00 - 13:20 - Giovanni Ceconello (Petronas, Italy) - Engine oil advanced technologies for FE improvement in modern HD applications [20]
- 13:20 - 13:30 - Symposium summary and closing  
Dr. Piotr Bielaczyc, on behalf of the International Organising Committee [10]
- 13:30 - 14:30 - Lunch [60]
- 14:30 - 16:30 - Tour of BOSMAL's laboratories  
Guide: Wojciech Trybus, Testing Laboratory Director, BOSMAL

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## The symposium programme

emission cars – the EU has made big steps regarding plans to introduce RDE to the approval procedures of cars from 2017; such tests and the accompanying emissions conformity factors will be mandatory, rather than any kind of “optional extra”. However, as always, the automotive market is not shaped only by political and technical factors, but also by customer requirements, which themselves also evolve. Both legislators and the general public have a common goal of reducing fuel consumption, without sacrificing durability or safety. Also, the increased media interest in the issue of exhaust emissions from modern cars (especially Diesels) increases the pressure on everyone involved in legislating, meeting and testing emissions. The response to that is a wide

range of advanced engine technology, catalytic aftertreatment systems, the development of fuels, lubricants and oils that reduce friction, and so on.

These solutions are often correlated: exhaust gas after-treatment systems require fuel with low sulphur content, advanced engine design defines the parameters of oil, etc. Fundamental changes in the powertrain (new energy sources, advanced electromechanical systems: hybrids) are a revolution in the industry. Requirements that emissions are below the prescribed level under almost all operating conditions may force the introduction of new technical solutions, or at least require extensive modification of current solutions. All of these new and modified technical solutions need to be de-



Prof. Jerzy Merkisz and Dr. Piotr Bielaczyc delivering the opening address



Wolfgang Thiel (TRT Engineering, Germany) during the opening presentation



veloped, tested, approved and certified – and, in light of RDE requirements – not only in the laboratory.

### Symposium organisation

Seeing that this subject is important for the further development of the automotive industry on a global scale as well as in the European Union and Poland, in the years 2010, 2011, 2012 and 2014 BOSMAL Automotive Research and Development Institute Ltd in Bielsko-Biala organized four international symposia on the problems of exhaust emissions from automotive sources. These symposia interested professionals from the automotive industry and academia, both foreign and from Poland, who willingly and frequently participated in the discussions. On 19-20 May 2016 BOSMAL and the Polish Scientific Society of Combustion Engines (PTNSS) was the organizer of the 5<sup>th</sup> International Exhaust Emissions Symposium. The organization and the programme of the symposium were prepared by the International Organizing Committee, headed by Dr. Piotr Bielaczyc (BOSMAL/PTNSS), with well-known specialists from the USA, Switzerland, the UK, Germany and Italy.

This is the fifth meeting in Bielsko-Biala with leading experts in this field from the US and Europe who discussed the American and European strategies for the development of low emitting vehicles, the latest trends in legislation and methods of emissions testing, the development of vehicular engines, fuels and lubricants. The aim of the meeting was to compare the factors mentioned above and discuss the possibility of legislation harmonization in the US and the EU, which would increase the possibility of control in certifying vehicles; the event also aimed to foster integration of the scientific community and the automotive industry at home and abroad, exchange of knowledge on many issues, as well as promoting the achievements of Polish research institutes in this field, particularly BOSMAL.

Media partners of the symposium included: “Combustion Engines” – a scientific journal published by PTNSS, “DieselNet” of Canada, “Przegląd Techniczny” and the “Gazeo” internet portal, the latter two from Poland.



Giovanni D'Urbano (FOEN, Switzerland) delivering his presentation on Swiss emissions standards

The symposium was attended by over 140 delegates, representing of 68 companies from the automotive and fuel industry, associated international organizations such as the ICCT and CONCAWE, research institutes and international academia from 20 countries (Japan, the USA, Canada, the UK, Spain,

Portugal, Italy, Switzerland, Austria, Luxembourg, Denmark, Belgium, Germany, the Netherlands, Norway, Finland, France, Slovakia, the Czech Republic and Poland).

Symposium guests were welcomed by BOSMAL Director Dr. Arkadiusz Stojcecki; the symposium was opened by Prof. Jerzy Merkisz, President of PTNSS.

### Symposium content

During the symposium 25 presentations were delivered on the impact of harmful emissions on human health, internal combustion engines, the development of vehicular powertrains, development of fuels and motor oils by well-known automotive exhaust emissions experts – see the full programme presented in the introduction. Additionally, there were 12 posters presented by specially invited experts from the field. The invited speakers presented during the five plenary sessions on the following topics: ‘The Automotive Emissions Landscape in the US and the EU’, ‘Emissions Reduction Technologies and Strategies’, ‘Real Driving Emissions’, ‘Particulate Matter Emissions and their Measurement and Control’ and ‘Fuel and Lubricant Development in Light of Emissions Requirements and Industry Trends’. Setting both the scene and the tone for the symposium, the symposium’s opening presentation was given by Dr. Piotr Bielaczyc of BOSMAL, who presented the most important technical, political and economic factors that currently affect the development of the automotive industry in the world, presented the history of the issue and attempts to regulate over the years, not only in the EU but also in the United States, China and India. He paid attention to current, real problems not completely taken into account by emissions regulations. He emphasized the problem of high emissions of NO<sub>x</sub> from modern diesel engines, the problem of particulate matter also emitted by spark ignition engines with direct injection and variance between actual measurements of fuel consumption and CO<sub>2</sub>, and those resulting from the NEDC cycle. The difference here reaches 30-50%. The problem of the road-laboratory gap regarding particulates and NO<sub>x</sub> will probably be solved by RDE, but the suitability of RDE for CO<sub>2</sub> measurements remains unclear. Typically, CO<sub>2</sub> emissions over the new cycle (WLTC) and the present cycle (NEDC) do not differ significantly; applying



Dr. Miriam Gerlofs-Nijland (National Institute for Public Health (RIVM) in Netherland) during a speech on the health consequences of emissions in road traffic



Mike Douba (Argonne National Laboratory, USA) delivering his presentation on test procedures for hybrids



Participants during the coffee break, viewing the climatic chamber (with 4WD chassis dynamometer) at BOSMAL

the full WLTP [procedure] improves the situation somewhat (mainly due to the redefined test inertia), but the road-laboratory gap has not yet been closed when it comes to CO<sub>2</sub>/FC. A number of questions asked in the summary of the opening presentation were touched upon and answered by presenters in further presentations. These theses for further discussion were:

- Will the introduction WLTP / RDE meet expectations and will have a measurable impact on air quality? After how many years will the results will be visible?
- Will the EU reduce its expectations for reducing fuel consumption and CO<sub>2</sub> emissions in the light of the more restrictive emission standards?
- Will the US continue its policy of aiming for zero emissions, or will fuel consumption become a bigger problem?
- Can emissions limits be reduced any further?
- Will PM/PN limits eventually apply to all vehicles? What about particles not originating from the combustion engine?
- Will consumers accept higher but more realistic fuel consumption; will it change the habits of buyers and engine offerings?
- Is it probable that the trends of recent years slow down/stop/reverse? Specifically:
  - Diesellisation – is the trend in the EU reversing? Is there scope for increased market share in the USA?
  - Downsizing/turbocharging
- What are the effects of current problems? How will the automotive industry survive?
- How to solve the problem of high NO<sub>x</sub> emissions inherent in downsized engines?
- When will it be possible to harmonize regulations in the USA, the EU (and beyond)?
- Is it possible to drastically reduce CO<sub>2</sub> emissions through improvement of conventional fuel types?
  - 100 RON – when could it be available on a global scale?

#### Legislation and proscribed test methodologies regarding exhaust emissions in the US and the EU

In the first session on regulations and methods of emissions testing the following individuals presented (inter alia): Dr. Vicente Franco (the ICCT, Germany), Kurt Engeljehringer (AVL, Austria), Giovanni D'Urbano (FOEN, Switzerland) who spoke about trends in reducing global emissions and their impact on measurement procedures and equipment.

Multiple presenters emphasized the fact that in the US the key elements of type approval include compliance testing of new and in-use vehicles, vehicle recalls and financial penalties, and a dedicated agency independent of local government (the EPA). The EU does not have many of these aspects – most significantly, there is no central authority responsible for the type approval and enforcement of regulations; nor is the creation of such an entity likely in the near future. Responsibility for these functions rests with individual member states. There is no harmonized approval system for the whole EU to organise vehicle recalls. (Recalls in the case of non-compliance with emissions standards are a true rarity in the EU, in contrast with the USA.) During the symposium it was highlighted that another problem is the lack of legal uniformity and regional variations in the interpretation of EU regulations, as a result of which it is difficult to say whether the ECU software used by some companies (for example) is actually breaking the rules or not. In spite of the frequency with which “defeat devices” are mentioned (in particular in recent months), there is a surprising lack of consensus on what such devices are and what kind of specific language could be used to ban them. Upcoming changes including RDE regulations will partially improve the situation in the EU, but without a centralized European body for approval of vehicles the US approach to the problem will continue to be more thorough. Experts discussed the incoming method for the measurement of emissions under actual driving vehicle on the road – RDE. The main objection regarding RDE is that measurements may be unreliable because of the very high number of external influencing factors. According to research by AVL (for example), NO<sub>x</sub> emissions can be measured with an accuracy of ±28%. There was much discussion of the WLTC chassis dynamometer driving cycle proscribed by the WLTP procedure (as described in UNECE GTR 15), which will soon replace the NEDC (as described in UNECE Regulation No. 83) and the cycles used in certain Asian countries.

China, which is always inspired by European emission standards, is currently planning to introduce China 6a, which is equivalent to Euro 6, but later China 6b is even twice as stringent. If fully implemented, it would mean that China would have the most stringent standards in the world, tested over the WLTP – a situation which would have appeared highly unlikely only a few years ago.

There were conversations on engine control strategies, which have significantly overtaken the development of





Prof. William Northrop (University of Minnesota, USA) during his presentation on particulates from low temperature combustion

legal requirements for type approval in Europe. In order to protect some engine and aftertreatment components, certain systems may be deactivated under certain conditions (e.g. EGR at cold start). In the EU, such control strategies are manufacturer secrets, while in the US such actions must be authorized. Federal US legislation also requires that vehicles are tested over multiple driving cycles, which include hot starts – in contrast to the EU, where there is one test cycle which always commences from a cold start. (This is another example of the thoroughness with which US emissions limits are enforced, for the time being without resorting to RDE testing.)



William Silvis (AVL Inc., USA) during his wide-ranging presentation on particulate emissions measurements

Dr. Miriam Gerlofs-Nijland (National Institute for Public Health and the Environment - RIVM, Netherlands) presented important information regarding the influence of the toxic compounds emitted by engines fuelled by biodiesel on living organisms.

### Methods of reducing engine emissions

The second session, focusing on emission reduction methods, was opened by a keynote delivered by Dr. Tim Johnson (Corning, USA). Among other topics, he talked about the possibilities for increasing the efficiency of vehicular engines.

The rather impressive figure of 45% thermal efficiency has been reached, but further development in this area is still possible. Figures which a few years ago seemed obtainable only in CI engines are now being reached in SI engines, although many of these engines are experimental and not market-ready; part-load efficiency remains an area for improvement. Naturally,

a large part of Dr. Johnson's keynote was dedicated to exhaust gas aftertreatment systems (selective catalytic reduction (SCR), SCR on filter (SCR-F), passive NO<sub>x</sub> absorbers (PNA), methane oxidation catalysts and gasoline particulate filters (GPF)). An important element for reducing emissions is the engine control strategy employed by the ECU – the calibration method of which was presented by Dr. Gerhard Schopp (Continental Powertrain, Germany). Due to the rapid development of the market for electric and hybrid vehicles there are doubts about that how to measure their actual emissions. The problems and future plans for emission measurement methods of hybrid vehicles have been presented by an expert from the US, a government research laboratory Mike Douba (Argonne National Laboratory, USA). Dr. Claus Goersmann (Johnson-Matthey, UK) presented his analysis of and predictions for future vehicles powered by low carbon fuels, which can reduce fuel consumption and CO<sub>2</sub> emissions by up to 15%. It was highlighted that diesel engines – recently so heavily criticized – should remain an important source of power due to their high efficiency. In spite of the growing popularity of electric vehicles, in 2025 97% of vehicles will still be powered by an internal combustion engine. That is why it is important to develop carbon production of alternative fuels and biofuels of low carbon intensity, as well as electricity from renewable sources.



Dinner and musical soiree at Kotuliński palace at the end of the first day of the symposium

Giovanni D'Urbano (FOEN, Switzerland) presented Switzerland's approach to emissions reduction. Mainly EU standards are employed in Switzerland, in some cases made more stringent, e.g. with reduced limits for emissions of particulate matter from construction machinery.

### Real-world emissions measurements: RDE testing

The third session related to RDE. The first RDE package has recently been published in Commission Regulation (EU) 2016/427; others are being finalised. Still under discussion is the matter of including cold start emissions, test procedures for hybrids and particle number measurements (RDE PN). Key findings and observations were presented by Helge Schmidt (TÜV Nord, Germany).

RDE tests that will be introduced to new approvals from September 2017 (with a conformity factor (CF) of 2.1) and next from January 2020 (CF = 1.5) require testing of the vehicle on the road using a portable emissions measurement system (PEMS). The route for the RDE includes driving in city traffic (urban), extra-urban and motorway. The route



Dr. Vicente Franco (The ICCT Europe, Germany) during his presentation on emissions standards in the EU and US



Guests during the coffee break, in the background the 500e electric car developed by BOSMAL

used by TÜV Nord is 83 km long and the test lasts 105 minutes (i.e. mean speed 57 km/h – higher than the equivalent values for WLTC and the NEDC).

### Methods of determination and reducing particulate emissions

The fourth session of the symposium focused on emission of particles, methods of their determination and control. Special attention was paid to mechanisms of particle formation. Prof. William Northrop (University of Minnesota, U.S.A.) showed the associations of solid particles emission in low temperature combustion processes. Biofuels were included in his considerations as well. He found that low temperature combustion leads to a decrease in soot emissions; however, the emission of CO and HC increases. Another American expert, William Silvis (AVL Inc., U.S.A.) presented advanced methods of solid particle emission measurement, allowing detection even where the particle population is very low, a pertinent point in view of future legislation (specifically California LEV III, which will limit gravimetric particulate emissions to 1 mg/mile). The topic of nanoparticles was also expanded upon by Dr. Topi Ronkko (Tampere University



Kurt Engeljehringer (AVL, Austria) during his presentation on global emissions regulations and emissions measurement methods

of Technology, Finland). He reported that the mean aerodynamic diameter of particles occurring in the exhaust gas of an engine running on CNG is lower than 10 nm. Dr. Mikko Moisio (De-kati, Finland) presented an advanced method of particle mass measurement based on a diffusion charger with electrometer.

### Development of fuels and lubricants for engines

The last, but just as important, part of the symposium dealt with the development of engine fuels and lubricants and their interactions with other powertrain systems. As expected, the topics of mineral oil-based fuels and possibilities for improvement of their properties, alternative fuels, biofuels and their manufacturing processes/technologies, possibilities of their application and compatibility with present infrastructure and vehicles were widely discussed – a keynote presentation was delivered by Dr. Thomas Wallner (Argonne National Laboratory, USA) on the US Department of Energy (DoE)'s project entitled: "Co-Optima (Co-optimization of engine fuels)", aiming at acceleration of the implementation of improved conventional fuels, low-cost and sustainable biofuels and highly efficient, low emitting engines for vehicle propulsion. Knut Skaardalsmo (Skaardalsmo Fuel Consulting, Norway) focused on the promising possibilities of methanol as an automotive fuel. Notably, methanol ( $\text{CH}_3\text{OH}$ ) may be obtained from natural sources and has the lowest carbon-to-hydrogen ratio of any liquid fuel. Dr. Heather Hamje (CONCAWE, Belgium) and Prof. Mirosław Wyszynski (the University of Birmingham, UK) presented the impact of advanced engine fuels on the emission of regulated and unregulated exhaust gas components. The part of the session on lubricants included the impact of soot on engine oil and the role played by low viscosity oil in fuel economy efforts. Representing Petronas (Italy), Giovanni Cecconello mentioned the topic of the development of low-viscosity oils (SAE 0W-20), providing low friction losses in internal combustion engines, in the context of engines powering heavy-duty vehicles. At this point it is worth recalling that diverse branches of the industry (e.g. light duty, heavy duty, motorsport, etc.) share certain problems and that solutions developed for a given branch can sometimes be transferrable to other branches – as an example, SCR for  $\text{NO}_x$  control has its origins in non-mobile applications.



Dr. Thomas Wallner (Argonne National Laboratory, USA) during his keynote presentation on the US Co-Optima programme

### Summary and Conclusions

The 5<sup>th</sup> International Exhaust Emission Symposium referred to the all questions related to the emission of hazardous exhausts emissions from automotive sources, including



observations and conclusions on the present and future legislative landscape on emissions and fuel economy, methods of emissions reduction and the development of research methods to aid in those goals.

The reduction of emissions of hazardous and toxic compounds is currently important – a reduction in emissions of solid particles (both in terms of mass and number), a decrease in real-world  $\text{NO}_x$  emissions, as well as meeting all demands during new types of tests (such as the WLTP and RDE) are the main challenges for the automotive industry caused by political, socioeconomic and technical factors. Fulfilling emission limits over the WLTC, as well as during RDE testing, is a very complicated and expensive process for vehicle producers, demanding increased investments into R&D, which for years has been among the main targets of BOSMAL, currently the largest R&D institution of this type in central/eastern Europe.

On the other side of the equation, legislators working on the implementation of advanced research methods and emission norms in Europe and elsewhere have to follow (and even anticipate) rapid developments in electronics and the computerization

of modern vehicles, and to implement vehicle type approval and in-use conformity procedures to ensure openness, clarity and to avoid conflict between vehicles manufacturers, vehicle users and regulatory authorities. Finally, it is worth recalling that while real-world exhaust emissions (e.g.  $\text{NO}_x$ , PN) cannot be measured by the average driver, real-world FC is automatically measured and displayed (and sometimes later shared on the internet) and this topic is of growing interest to consumers.

All presentations given during the 5<sup>th</sup> International Exhaust Emission Symposium (5<sup>th</sup> IEES), together with accompanying material, have been archived in the official conference proceedings entitled: Symposium Proceedings – “Trends in automotive emissions, fuels, lubricants and test methods – a global view with focus on the EU & US”, ISBN No 978-83-931383-9-5 and in the Book of Abstracts, ISBN No 978-83-946334-0-0, published by BOSMAL on CD, together with movie reportage on DVD. Addy Majewski of DieselNet (Canada) prepared a summary/analysis of the symposium, which is available online [14]. A summary of the symposium has also been published in the Polish journal “Przegląd Techniczny”.

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