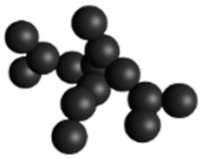
2017



Cambridge Particle Meeting

Book of Abstracts

23rd June 2017

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8:30	**REGISTRATION**		
	Session I (Chair: Jonathan Symonds)		
9:00			Welcome
9:10	David Kittelson	University of Minnesota	Particle number measurements: Correcting for losses at 10 nm or smaller
9:30	Justin Koczak	University of Michigan	Morphology and Nanostructure of Size-Selected Ultrafine Particles Emitted by a Gasoline Direct Injection Engine
9:50	Felix Leach	University of Oxford	Particulate Emissions from a Highly Boosted GDI engine
10:10	Jacob Swanson	Minnesota State University	On-road particle and gaseous emissions from a PFI and GDI hybrid electric vehicle
10:30	**BREAK**		
	Session II (Chair: Adam Boies)		
11:00	Suzanne E. Paulson	University of California, Los Angeles	The Design of the Built Environment, the Roadway Pollutant Concentrations and Pedestrian Exposure in Complex Urban Areas
11:20	Steven Barrett	Massachusetts Institute of Technology	Particulate matter and aviation contrails
11:40	Marc Stettler	Imperial College London	Aircraft Black Carbon Particle Number Emissions – New Predictive Method & Uncertainty Analysis
12:00	Mike Adams	University of Leeds	Ice nucleating particle concentration during a combustion aerosol event
12:20	Arvind Thiruvengadam	West Virginia University	Investigation of DPF failure modes- Effect on particle number, size distribution, and failure identification strategies
12:40	**LUNCH & POSTER SESSION**		
	Session III (Chair: Martin Irwin)		
13:40	Tyler Johnson	University of Cambridge	Theory and Experimental Validation of the Steady-State AAC Data Inversion
14:00	Mario Schriefl	Graz University of Technology	Investigation of a Piezoelectric Plasma Generator as a Charging Source for Aerosols
14:20	Marin Vojkovic	Université de Lille	Surface chemical analysis of soot aerosol by Two-step Laser Mass Spectrometry: Improvements of sensitivity and selectivity
14:40	Nickolas Eaves	University of Cambridge	Experimental and computational study of the evolution of soot particle morphology in a diluted laminar co-flow ethylene diffusion flame
15:00	Hamisu Dandajeh	University College London	Effect of molecular structure of C1 – C7 hydrocarbons on PAH formation
15:20	**BREAK**		
	Session IV (Chair: Robert Nishida)		
15:50	Martin Irwin	Cambustion Ltd.	Obtaining the mixing state of black carbon using the CPMA-SP2 method; from concept to the field
16:10	David Green	King's College London	High time resolution measurements of PM2.5 and PM10 using X-ray fluorescence
16:30	Yuchieh Ting	University of Manchester	The Processes and Emissions of Residential Solid Fuel Combustion from Cooking Stoves.
16:50	Gordon Andrews	University of Leeds	Particle size distribution as a function of time during pine wood combustion on a cone calorimeter
17:10	**END**		

Posters

Group 1: Ambient Air, Emissions

1.01	**Chung Ting Lao**	University of Cambridge	Modelling secondary particulate emission from diesel particulate filters
1.02	**Colin Baker**	PCME Ltd	Continuous Emissions and Flow Monitoring for Industrial Processes
1.03	**D. Vignelles**	LPC2E / CNRS	Evaluation of the miniature particle counter LOAC for the survey of stratospheric aerosols with meteorological balloons
1.04	**Dmitriy V. Kornilin**	Samara National Research University	Method and device for efficiency estimation of abrasive cleaning tool
1.05	**Hamish Nash**	University of Cambridge	Catalytic Stripper Solid Particle Penetration and Semi-Volatile Removal Characteristics
1.06	**Jochen A.H. Dreyer**	University of Cambridge	Experimental study of soot evolution in vapour-fed co-flow diffusion flames
1.07	**Meisam Babaie**	University of Salford	Particle Emissions of a Diesel Car during Real World Urban Driving
1.08	**Roger Teoh**	Imperial College London	Aircraft Black Carbon Particle Number Emissions – New Predictive Method & Uncertainty Analysis

1.09	**Thomas Whitney**	University of Cambridge	Design and Testing of a Wireless Sensor Platform for On-road Measurement of Emissions and Energy Use
1.10	**Yanlong Wu**	University of Leeds	Comparison of PN measurements from emissions of a miniature combustion aerosol standard soot generator.
1.11	**Hu Li**	University of Leeds	Particle size distribution as a function of time during pine wood combustion on a cone calorimeter
1.12	**H. Mat Kiah**	University of Leeds	Particle size emissions from PVC electrical cable fires

Group 2: Fundamentals, Nanotechnology

2.01	**Astrid Boje**	University of Cambridge, Nanyang Technological University	Computational study of temperature effects in TiO2 synthesis in an industrial reactor
2.02	**Brian Graves**	University of Cambridge	Continous Production of Carbon Nanotube Fibres and Mats using Microwave Plasma
2.03	**Carlos E. Garcia**	Imperial College London	Experimental Validation of a Silica Nanoparticle Formation Model
2.04	**Jean de la Verpilliere**	Echion Technologies, University of Cambridge	Carbon Nanotube Sea Urchins for Li-Ion Batteries

2.05	**Louie Chen**	Airmodus Ltd., Scielutions	Using a MultiCPC system to measure particle size distribution generated by a plasma lighter
2.06	**Robert Nishida**	University of Cambridge	Measuring Ultrafine Aerosols by Direct Photoionization and Charge Capture
2.07	**Vilhelm Malmborg**	Lund University	In-situ XPS on Carbonaceous Nanoparticles
2.08	**Manoel Y. Manuputty**	University of Cambridge	Aggregate formation in stagnation flame synthesis of TiO2: A modelling and experimental investigation.

09:10-09:30 – David Kittelson
Particle number measurements: Correcting for losses at 10 nm or smaller

David Kittelson*

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In the EU “solid” particles larger than 23 nm from Diesel and SI engines (ground vehicles) are regulated. This regulation was originally developed on the assumption that it would apply to diesel vehicles and would force the use of high efficiency particle filters. This happened and now “solid” number emissions from new diesel vehicles are very low. However, other engine technologies that don’t use exhaust filters like spark ignition direct injection gasoline and spark ignition natural gas produce significant “solid” particle number emissions - and many of these particles are smaller than 23 nm. “Solid” particle mass (black carbon) and “solid” particle number larger than 10 nm from aircraft turbine engines will be regulated worldwide starting in 2020. A major problem with measuring particles smaller than 23 nm is correcting for losses in the sampling and sample conditioning system. The aircraft method uses the measured mass to number ratio to estimate particle size in order to make size dependent loss correction. This requires that both mass and number be measured with fast response instruments. The present EU method measures instantaneous solid particle number but time-integrated total particle mass, thus the aircraft line loss correction method cannot be used. These issues will be discussed and a new method for determining a size loss correction will be presented.

09:30-09:50 – Justin Koczak
Morphology and Nanostructure of Size-Selected Ultrafine Particles Emitted by a Gasoline Direct Injection Engine

Justin Koczak*[1], Andre Boehman[1], Matt Brusstar[2], Frank Ruiz[3]

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A number of researchers have shown that modern GDI engines emit very large numbers of particles, particularly with sizes less than 100 nm, despite low mass emissions. Particle number reduction (via filtration or specialized engine calibrations) is a highly sought after goal in light of upcoming regulations. However, in just considering the number or mass of the particles, a large wealth of information is ignored, including particle morphology, structure, and chemical composition. Additionally, all particles classified into a particular size or size range do not necessarily have the same (or even similar) properties. It is useful for health effects research, filtration studies, secondary aerosol formation research, and regulation development to understand the size dependence of the aforementioned properties. This work seeks to shed light on these areas by exploring fuel injection parameters (e.g., number of injections, injection pressure, apportioning of fuel into different injections, and the timing of the various injections).

This study only considered physical characteristics. A matrix of twelve test points was created examining two injection pressures for three different triple fuel injection strategies, each at two different loads. A single-cylinder research engine was used. Combustion phasing, engine speed, and global equivalence ratio were held constant for the studies. The fuel was E0 Tier II EPA certification gasoline. Particles were obtained by using a custom-built two stage ejector pump dilution system. Size distributions were obtained with a TSI SMPS system (3080 classifier with 3081 DMA and 3776 CPC). Five cut points were selected from this distribution, being the mode and four steps of 30 nm above and below the mode. The particles were sampled onto TEM grids using a Naneos Partector TEM sampler. The collected particles were imaged in a JEOL 3011 HRTEM, and the images were processed using propriety codes. Both low resolution and high resolution studies were conducted to understand the morphology and nanostructure, respectively, of the collected particles.

The vast majority of particles collected were aggregates. For the smaller sizes, singlets, doublets, and triples were observed. Across all operating conditions, and in the sizes examined for each of the conditions, the morphology of the particles varied widely. Many particles were long aggregates with fractal dimensions closer to one, while others were collapsed aggregates with fractal dimensions closer to three. Primary particle diameters and quantity per aggregate varied widely. High injection pressure reduced concentrations and primary particle diameters. A great deal of variability was observed to occur in the analyzed results, but this is partly a consequence of some images not being well-suited for image analysis, a limited sample size (although at least 25 images were taken for each sample), and the limitations of the image analysis code. As of this writing, the author is still analysing high resolution images, so for now, the comments on high resolution results will be left out (they will be addressed at the conference in June). It is expected that features such as fringe length, fringe spacing, tortuosity, and other results for non-amorphous primary particles will be available and discussed.

09:50-10:10 – Felix Leach
Particulate Emissions from a Highly Boosted GDI engine

Felix Leach[1], Richard Stone[1], David Richardson[2], Andrew Lewis[3], Sam Akehurst[3], James Turner[3], Sarah Remmert[4], Steven Campbell[4], Roger Cracknell[4]

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Downsized, highly boosted, GDI engines are becoming the preferred gasoline engine technology to ensure that increasingly stringent fuel economy and emissions legislation are met. The Ultraboost project engine is a 2.0 L in-line 4-cylinder prototype engine, designed to have the same performance as a 5.0 L V8 naturally aspirated engine but with reduced fuel consumption. It is important to examine Particle Number (PN) emissions from such extremely highly boosted engines to ensure that they are capable of meeting current and future emissions legislation. The effect of such high boosting on PN emissions is reported here for a variety of operating points and engine operating parameters.

The effect of engine load, air fuel ratio, fuel injection pressure, fuel injection timing, ignition timing, inlet air temperature, EGR level, and exhaust back pressure have all been investigated. It is shown that PN emissions increase with increases in cooled, external EGR and engine load, and decrease with increases in fuel injection pressure and inlet air temperature. PN emissions are shown to fall with increased exhaust back pressure, a key parameter for highly boosted engines. The effects of these parameters on the particle size distributions from the engine have also been evaluated. Significant changes to the particle size spectrum emitted from the engine are seen depending on the engine operating point. Operating points with a bias towards very small particle sizes were noted.

10:10-10:30 – Jacob Swanson
On-road particle and gaseous emissions from a PFI and GDI hybrid electric vehicle

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Hybrid electric vehicles (HEVs) are regarded as a key technology to reduce the impact of internal combustion engines on air pollution and greenhouse gasses. HEVs have an advantage in market penetration due to their lower cost and higher driving range compared to fully electric vehicles (EVs). On the other hand, HEVs still emit air pollutants due to the presence of internal combustion engine. In this study, the total particle number (PN), solid particle number (SPN), particulate matter (PM), and oxides of nitrogen (NOx) emissions from two HEVs, a Toyota Prius and Hyundai Sonata, were measured,. These vehicles have major differences in engine techonlogy such as PFI (port fuel injection) vs GDI (gasoline direct injection). During an on-road test, HEV exhaust was diluted using a rotary disk dilutor. PN was measured with a Detaki E-filter and TSI EEPS while SPN was measured after thermal conditioning using a TSI 379020 rotating disk thermal dilutor. NOx was measured using a NTK raw exhaust sensor. Emissions were evaluated over city, and highway driving routes in Minneapolis, Minnesota during winter time (average temperature ~ 2°C to 7°C). We attempted to better elucidate the nature of emissions from HEVs with focus on 1) on-road emission characteristics, 2) cold-cold-starts and 3) re-ignition events. One example of an operating condition unique to HEVs is that they turn off already a warmed-up engine when the battery is charged enough during CS (charge sustaining) mode. This characteristic leads to energy efficient driving, but the engine can have multiple cold-starts and re-ignition events, which can increase engine emissions unexpectedly. We observed that the emissions for PN and PM from GDI technology (Sonata HEV) were much higher than that of PFI technology (Prius HV). Interestingly, NOx emissions of the Prius HEVs were much higher than that of Sonata HEVs in the city driving condition, whereas in the highway condition shows that the comparable level of NOx emissions. The study also compared fuel economy of the HEVs under real-world driving conditions.

11:00-11:20 – Suzanne E. Paulson
The Design of the Built Environment, the Roadway Pollutant Concentrations and Pedestrian Exposure in Complex Urban Areas

Wonsik Choi[1,3], Dilhara Ranasinghe[1], J.R. DeShazo[2], Lisa Wong[2] and Suzanne E. Paulson[1]*

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This study attempts to explain explicitly the direct and quantitative effects of complicated urban built-environment on near-road dispersion and levels of vehicular emissions at the scale of several city blocks, based on ultrafine particle concentrations ([UFP]), and considers the potential for reducing pedestrian exposure from careful location of bus transit stops. Measurement sites in the Los Angeles area with a wide range of built environments but similar mesoscale meteorology were explored. After controlling for traffic, In the calm mornings, block-scale [UFP] showed a strong relationship with a combination of the area-weighted building height, the amount of open space, and the building footprint. In the afternoons, however, vertical turbulence intensity □w was the most effective factor controlling [UFP]; under these conditions, the surrounding built environment appears to play an indirect role in observed [UFP], by affecting surface level turbulence. The effects are substantial; controlling for traffic, differences in Ararea and building heterogeneity were related to differences in [UFP] of factors of two to three among our five study sites. Moving or designing transit stop locations is a relatively low cost mitigation strategy to reduce pedestrian exposure in urban areas. Using 1,744 cross-intersection concentration profiles of ultrafine particles with 5 m spatial resolution, from 10 signalized intersections at six urban sites with distinct built environments for both morning and afternoon, we investigate how UFP decay around intersections. The UFP peak concentrations were located near the intersections, and averaged about 90% higher than the minima along the blocks, with a rapid decay profile. Simple time-duration exposure calculations combined with breathing rates suggest moving a bus stop farther from the intersection reduces transit-users' exposure levels to the total UFP by up to about 60 % for the sites studied here.

11:20-11:40 – Steven Barrett
Particulate matter and aviation contrails

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This talk will explore the role of particulate matter in aviation contrails. Topics will include the influence of directly emitted particulate matter on contrail microphysical properties and radiative forcing, the role of background atmospheric aerosols, and engineering approaches to reducing the radiative impact of contrails.

11:40-12:00 – Marc Stettler
Aircraft Black Carbon Particle Number Emissions – New Predictive Method & Uncertainty Analysis

Roger Teoh[1], Marc Stettler[1]*

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Black Carbon (BC) particle number emissions from aircraft jet engines contribute not only to anthropogenic climate change, but also on the deterioration of human health. The largest uncertainty in evaluations of civil aviation's impact on the climate is the contribution of BC particles to the formation of contrails, which have a significant and short-lived climate impact. Previous studies have shown that the number of contrail ice particles is strongly correlated with the number of BC particles emitted by aircraft engines.

At present, existing methods to estimate the BC particle number emissions index (EIn), the number of BC particles per kg of fuel, are limited by several assumptions, including that BC aggregate morphologies remain constant irrespective of thrust settings. Using a bottom-up approach based on fractal aggregate theories, this paper proposes a new method to estimate EIn for global civil aviation.

BC EIn estimates calculated using this new approach have been validated and agree well with direct measurements from both ground and cruise conditions. A review of its model input parameters such as different BC mass emissions (EIm) methodologies available, Geometric Mean Diameter (GMD), and Geometric Standard Deviation (GSD) have also been conducted prior to performing an uncertainty and sensitivity analysis.

The new BC EIn predictive model is subsequently applied to an aircraft activity sample dataset from the Aviation Environmental Design Tool (AEDT). This subset consists of 3371 individual flights during cruise, which parameters are mainly captured by the US FAA radar coverage from the 9th to 11th of March 2006. Preliminary analysis suggests the average BC EIn to be around 1.2x1015 #/kg-fuel, around 85% higher than previous estimates.

This higher number of estimated BC EIn in the baseline scenario implies a smaller contrail ice particle diameter, potentially increasing its optical depth and radiative forcing. Several topics are identified for further research.

12:00-12:20 – Mike Adams
Ice nucleating particle concentration during a combustion aerosol event

M. Adams[1]*, D. O'Sullivan[1], G.Porter[1], Jesus Vegera-Temprado[1], Mark Holden[1], Federico Carotenuto[2], A. Sánchez Marroquín[1], M.D. Tarn[1], A. Harrison[1], J. McQuaid[1] and B. J. Murray[1]

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The formation of ice in supercooled clouds is important for cloud radiative properties, their lifetime and the formation of precipitation. Cloud water droplets can supercool to below -33°C, but in the presence of Ice Nucleating Particles (INPs) freezing can be initiated at much higher temperatures. Hence, there is the potential for anthropogenic aerosol emissions to exert an influence on clouds, climate and the hydrological cycle through the nucleation of ice. The concentration of combustion aerosol, particularly black carbon, has increased dramatically since pre-industrial times and therefore combustion aerosol have the potential to exert a cloud glaciation forcing on the climate system. In order to investigate the effectiveness of combustion aerosol as INPs we made measurements of INP concentrations at a background urban location (i.e. some distance from point sources of aerosol) over a specific combustion aerosol event. The combustion aerosol event was on the 5th November which is a major bonfire and firework event celebrated throughout the UK to celebrate the thwarting of a plot to destroy the houses of parliament in 1605. During the event no significant increase was observed in INP concentration despite a factor of ~10 increase in aerosol number concentrations and a factor ~100 increase in black carbon concentration. This implies that black carbon and combustion aerosol did not compete with the INP present in background air during this event. Furthermore, an upper limit for the number of active sites per surface area of black carbon (ns) was determined and compared to estimates in the literature. We conclude that combustion aerosol event such as this are not a major source of INP, but we cannot rule out combustion aerosol being important when the background INP concentrations are lower.

12:20-12:40 – Arvind Thiruvengadam
Investigation of DPF failure modes- Effect on particle number, size distribution, and failure identification strategies

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The use of DPF has resulted in near zero soot emissions from current technology diesel engines. Current technology DPFs are designed for durability and to last the useful life of the engine. However, both the industry and regulators are observing DPF failures that could be linked to failure of other engine subsystems upstream the filter. For instance, failure of EGR and boost pressure system could result in excessive engine-out PM emissions which could subsequently lead to a DPF failure. However, the type of failure, its root cause and the resulting effect on PM number and mass emissions has not been illustrated. Its common hypothesis that a failed DPF will result in non-compliance to PM emissions standards. However, the type of failure would dictate whether the soot slip will result in increased number or mass emissions. Therefore, an analysis of particle size distribution, number and mass concentration, related to the different magnitudes of DPF failure is necessary to build robust failure identification pathways.

This study aims to correlate the conventional approach of using differential pressure sensor to soot and solid PM number emissions from a failed DPF. The ongoing study includes controlled engine testing to simulate DPF failure and characterize the resulting soot and PM number and mass emissions. The simulated different DPF failures are aimed correlating the changes in differential pressure readings to its corresponding magnitude of soot slip through the DPF. The correlation of the type of failure to the PM number and size distribution from the tail-pipe of a HDD engine will be essential in developing OBD monitors for identifying both PM mass and number, before triggering the malfunction indicator. The study uses AVL Microsoft sensor TSI EEPS and a miniature tailpipe soot sensor to measure tailpipe PM emissions downstream of a failed and partially failed DPF.

13:40-14:00 – Tyler Johnson
Theory and Experimental Validation of the AAC Data Inversion

T.J. Johnson[1]*, M. Irwin[2], J.P.R. Symonds[2], J.S. Olfert[3] and A.M. Boies[1]

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The Aerodynamic Aerosol Classifier (AAC) is a novel instrument that generates a controlled sheath flow rate and rotational speed to induce known drag and centrifugal forces on each nanoparticle sampled. Particles with aerodynamic diameters smaller than the AAC setpoint remain entrained in the sheath flow, while larger aerodynamic diameters impact the outer surface of the classifier. Therefore, only particles with the correct aerodynamic diameter pass through the AAC classifier (Tavakoli & Olfert, 2013).

To accurately measure an aerosol's aerodynamic size distribution using an AAC, its transfer function was experimentally characterized using a tandem AAC (TAAC) setup. A poly-dispersed aerosol with a known particle morphology and density was generated by nebulizing a low vapor pressure oil. The upstream AAC was set at a constant setpoint and selected one aerodynamic diameter from the poly-dispersed aerosol. The downstream AAC then stepped through the aerodynamic diameter domain of the classified particles and recorded the corresponding doubly classified particle concentration at each setpoint. Similar to Martinson et al.'s (2001) characterization of the Differential Mobility Analyzer (DMA) transfer function, a transmission efficiency and transfer function width factor were applied within the theoretical triangular AAC transfer function to capture non-ideal behaviour, such as particle diffusion and losses. These factors were determined by fitting the theoretical TAAC convolution through chi-squared minimization to the experimental TAAC data at different particle aerodynamic diameters and sheath flow rates.

The steady-state AAC data inversion was then developed to calculate an aerosol's aerodynamic size distribution ($dN/d\log d_a$) from the primary AAC measurements (particle number concentration, N as a function of particle aerodynamic diameter, d_a), including the transmission and width factors previously determined. This inversion was validated by comparing the particle size distributions measured by the AAC and Scanning Mobility Particle Sizer (SMPS) of the same poly-dispersed aerosol with a known effective particle density.

Bibliography

Martinsson, B. G., Karlsson, M. N. A., & Frank, G. (2001). Methodology to Estimate the Transfer Function of Individual Differential Mobility Analyzers. Aerosol Science and Technology, 35(4), 815–823. https://doi.org/10.1080/027868201753227361

Tavakoli, F., & Olfert, J. S. (2013). An Instrument for the Classification of Aerosols by Particle Relaxation Time: Theoretical Models of the Aerodynamic Aerosol Classifier. Aerosol Science and Technology, 47(8), 916–926. https://doi.org/10.1080/02786826.2013.802761

14:00-14:20 – Mario Schriefl
Investigation of a Piezoelectric Plasma Generator as a Charging Source for Aerosols

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Recently, a new low-cost piezoelectric Plasma generator, called CeraPlas™, was developed by EPCOS OHG. This device allows for high efficient gas ionization at atmospheric pressure and temperature conditions at secure operating conditions. The dimensions, as well as the power consumption of the device enable its usage for mobile applications (PEMS). Depending on operating power, surrounding gas flow rate and position downstream of the device, an ion density of up to 2 x 10^{13} m^{-3} for both, positive and negative polarities, can be achieved.

In this study, we investigated the applicability of the device as a bipolar charging source for aerosols. For this purpose, the device was mounted in an apparatus which enables the measurement of the ion current using electrostatic precipitation. The CeraPlas™ was operated in an N_2 atmosphere, ensuring reproducible working conditions and minimizing generation of ozone. With this setup, the device was characterized with respect to ion densities at different working conditions (operating power, gas flow rates and measurement positions).

Moreover, a mixing chamber for aerosols and ions for aerosol charging was designed. A multiphysical simulation of the mixing chamber was performed, including fluid dynamics, transport of the ion species and particle trajectories. Assuming an ion recombination coefficient of 1.6 x 10^{12} m^3s^{-1}, the Nit product was estimated to be ~10^{12} $m^{-3}s$.

The bipolar charger was used as a neutralizer for a differential mobility analyser and tested against commercially available bipolar aerosol chargers (x-ray source and radioactive source). First promising results show comparable charging efficiencies. Nevertheless, enhancement of the charging chamber – in order to increase the N_it product – as well as the determination of charge distributions of the charged particles is ongoing.

14:20-14:40 – Marin Vojkovic
Surface chemical analysis of soot aerosol by Two-step Laser Mass Spectrometry: Improvements of sensitivity and selectivity

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Current high interest in pushing the selectivity and sensitivity limits of analytical methods based on laser ablation/desorption in order to probe the (surface) chemical composition of nanoscale particles is motivated by their high environmental and health impact. The refinement of our experimental setup based on Two-step Laser Mass Spectrometry (L2MS) technique applied to soot particles chemical characterization, allows us to improve the sensitivity and the ability to detect various aromatic and aliphatic compounds adsorbed on the soot surface. The analyses are carried out on field and laboratory soot samples obtained from standard flames, and also on "surrogate" (model) soot, which was produced by adsorbing well-defined amount of polycyclic aromatic hydrocarbons (PAH) mixtures on a black carbon matrix of known specific surface. PAH solutions in various concentrations are mixed with black carbon particles and then deposited on a borosilicate filter in the vacuum filtration process. Using this procedure, we obtain samples with well-defined surface concentrations of PAHs which are used to measure the limit of detection for our set-up and to calibrate its sensitivity.

The experimental setup consists of 266 nm or 532 nm nanosecond desorption laser beam (respectively 4^{th} or 2^{nd} harmonic of a nanosecond Nd^{3+}:YAG laser) that probes the sample surface. The desorption step is followed by one of three different ionization schemes. The first one uses the 4^{th} harmonic of a Nd^{3+}:YAG nanosecond laser (266nm) to ionize the desorbed species by Resonant Two-Photon Ionization (R2PI). Only species with absorption bands around 266 nm and sufficiently low ionization energy (<9.2 eV), especially polycyclic aromatic hydrocarbons (PAHs) are observed with this ionization wavelength. The second wavelength is 157 nm (7.9 eV), produced by an F2 excimer laser. Its photon energy is sufficient for the Single-Photon Ionization (SPI) of most PAHs. The third wavelength is 118 nm (10.5 eV), i.e. the 9^{th} harmonic of the nanosecond Nd^{3+}:YAG laser, produced by four wave mixing in a home-made Xe cell. This photon energy is sufficient to ionize most of the condensed phase species, especially aliphatic species.

The wavelength influence is tested, first on model soot, and after on "real" (laboratory and field) soot samples. Results for model soot were used to evaluate the differences in detection limits, as well as the ionization efficiency of different species. Further analyses were performed to evaluate the influence of particle size distribution for real and model to gain a better understanding of its effects. Different ionization schemes used allow us to obtain complementary mass spectra and to draw a more complete picture of the soot surface composition.

14:40-15:00 – Nickolas Eaves
Experimental and computational study of the evolution of soot particle morphology in a diluted laminar co-flow ethylene diffusion flame

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A study on the evolution of soot particle morphology in a diluted laminar co-flow ethylene diffusion flame is performed. Spatially resolved experimental measurements for temperature are obtained via thermocouples and for average aggregate radius of gyration and primary particle diameter are obtained via transmission electron microscopy (TEM) of thermophoretically sampled particles. The trends in the morphological data are discussed with regards to height above the burner and radial distance from the centreline. Numerically, the CoFlame code is utilized to compute the 2D gas-phase flow, temperature, and species fields. The code includes a population balance model (PBM) using the sectional method such that the effect of soot formation processes on the gas-phase species field can be approximately accounted for. The 2D fields are used as inputs to a detailed PBM that includes a complete description of particle morphology and which utilizes stochastic particle methods. The initial detailed PBM computations are in satisfactory agreement with the experimental measurements presented in this work and in previous works for soot volume fraction and optical band gap. A parametric sensitivity analysis is performed to understand the effect of model parameters on the predicted soot morphology and previous measurements.

15:00-15:20 – Hamisu Dandajeh
Effect of molecular structure of C1 – C7 hydrocarbons on PAH formation

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The influence of molecular structure of a homologous series of ten hydrocarbons (methane, ethane, ethylene, acetylene, propane, propylene, butane, iso-butane, heptane and toluene) on PAH formation was investigated in a laminar tube reactor. The hydrocarbons underwent oxygen free pyrolysis in the temperature range of 1050 to 1350 ^{o}C at a fixed carbon concentration of 10,000 ppm on C_1 basis. The environment and range of temperatures in the reactor resembled, to a degree, the conditions in the core of a diesel engine fuel spray (oxygen limited zone). Particulate and gas phase PAHs were collected at the outlet of the reactor at temperature intervals of 100 ^{o}C. The particulates generated were characterised at sub-micron levels in terms of size, number and mass using a differential mobility spectrometer (DMS-500) instrument. PAHs from the particulate and gas phase samples were extracted using an accelerated solvent extraction (ASE) system and the extract was then analysed using gas chromatography coupled with mass spectrometry (GCMS). The PAHs studied were the US EPA 16 priority PAHs with particular attention given to group B2, which are possible human carcinogens.

Results from this investigation showed that increasing the carbon number of saturated acyclic C_1 – C_7 hydrocarbons decreased the gas phase (GP) PAH concentrations at a temperature of 1350 ^{o}C, while the particulate phase (PP) PAH concentrations (as well as those of Group B2 PAHs) decreased at a temperature of 1150 ^{o}C. At 1050 ^{o}C, total PAH concentration increased with increasing carbon number, while at 1350 ^{o}C, total PAH concentration were found to decrease with carbon number. Lighter benzenoid and five-membered ring PAHs were detected in roughly similar concentrations regardless of the carbon number of the hydrocarbon. Isomerisation in the C_4 hydrocarbons and aromatisation in the C_7 hydrocarbons increased substantially, the soot propensities, the abundance of particle phase PAHs and carcinogenicity on volume of gas basis at the temperature of 1050 ^{o}C.

Degree of unsaturation of C_2 and C_3 hydrocarbons (ethane, ethylene, acetylene, propane and propylene) was also investigated and found to play an important role on the type and concentration of PAHs per unit mass of soot and per unit gas volume. It was observed that increasing the unsaturation of a fuel increases its gas phase PAHs in the case of the C_2 fuels and particle phase PAHs in the case of the C_3 fuels. The total PAH distribution was therefore dominated by the gas phase PAHs in the C_2 fuels and particle phase PAHs in the C_3 fuels.

15:50 - 16:10 – Martin Irwin
Obtaining the mixing state of black carbon using the CPMA-SP2 method; from concept to the field

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Refractory black carbon particles (rBC) significantly contribute to warming effects in the atmosphere, altering the climate system, and also pose significant health risks. These impacts are especially efficient at regional hotspots with high emissions of pollutants, such as in fast-developing megacities. These urban environments have the most population exposure, and improving the understanding of the sources and the processing of pollutants in these environments is critical in guiding policy making. Here we present the methodology and results of a new technique to improve understanding of the mixing state of rBC. The mixing state of rBC is most simple envisaged as a core-shell model with a rBC core and non-rBC shell (its coating) comprising a single particle. The mixing state of rBC is crucial to determine its lifetime in the atmosphere, optical properties, and physicochemical characteristics.

To date, precisely quantifying the rBC mixing state has posed a challenge, due in part to complex particle morphology. We have applied morphology-independent measurements of rBC mixing state on a single-particle basis firstly as a proof-of-concept chamber study, in order to develop the an inversion model, and secondly as part of a field deployment in central Beijing in November 2016. The measurement technique can be summarised as follows: mono-dispersed particle mass (M_P) is selected using a Centrifugal Particle Mass Analyser (CPMA, Cambustion Ltd) and a single particle soot photometer (SP2, DMT inc.) is used downstream of the CPMA to measure the rBC mass (M_{rBC}). The full scan of CPMA masses (21 mass bins covering most of M_P) are performed every half hour (typically following polydispersed particles measured without running CPMA).

As the chamber experiments were controlled precisely, the results are useful in testing the inversion. For bare rBC, the individual particle mass, M_P, is equal to the individual particle M_{rBC}. After loading the rBC aerosol with significant coating, M_P is far higher than MrBC; thus the coating mass can be directly derived. Integration of the mass distributions results in total mass of rBC and coating material. For the Beijing field experiments, there is significant faction of particles with M_{rBC} lower than M_P, and as with the chamber experiments, the difference between M_P and M_{rBC} defines the coating mass. This set up will give the full picture of rBC and coating distributions, allowing a comprehensive examination of rBC mixing state at each particle mass. These results will provide important information to understand the source distribution, emissions, lifetime, and optical properties of rBC under complex environments in Beijing.

16:10-16:30 – David Green
High time resolution measurements of $PM_{2.5}$ and PM_{10} using X-ray fluorescence

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Advances in measurement instrumentation have resulted in the ability to quantitatively measure a wide range of aerosol chemical composition at a high time resolution (every 1 hour or less) without the need for costly and time consuming laboratory analysis. However, measuring the concentration of metallic and mineral elements has remained problematic and many receptor modelling studies still rely on collecting material and subsequent laboratory analysis.

This study reports the results of measurement campaigns using a high time resolution XRF-based analysis system (XACT 625, Cooper Environmental. These measurements were made close to traffic sources in London and close to three industrial sites in the UK. These results demonstrate the importance of metallic and mineral elements to both the mass of $PM_{2.5}$ and PM_{10} and as well-conserved tracers for specific sources. These sources have been de-convolved using the Multilinear Engine (ME-2 solver) and provide a source apportionment based on the positive matrix factorization algorithm (PMF).

Comparisons with co-located filter based and laboratory measurements will be reported to demonstrate continuity with existing measurement methods. Further, a novel laboratory based cross calibration between the XRF and a direct measurement is also reported.

16:30-16:50 – Yuchieh Ting
The Processes and Emissions of Residential Solid Fuel Combustion from Cooking Stoves.

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Solid fuels such as wood and charcoal are widely used as the primary sources for cooking and heating especially in the developing countries, with severe impacts on human health, air quality and climate. The source profiles are important for initializing models to investigate their subsequent impact on air quality and climate, however such information for residential solid fuel burning is scant and introduce one of largest uncertainties. In this study, the characterization of the emissions from residential solid fuel burnings was provided by simulating combustion conditions in a dilution tunnel using real-world cooking stoves that are used in the developing world with a range of solid fuels, providing fundamental information that will underpin future mitigation strategies. A series of solid fuel combustion experiments were conducted at the combustion test facility with a heating stove (willow logs, pine and coal), two 'improved' cook stoves (dry willow sticks, dry/wet oaks and charcoal) commonly used in Western Africa and a small-scale pyrolytic wood stove (wood pellets) used in Ethiopia and Zambia. The sub-micrometer non-refractory aerosol compositions and concentrations were determined by an aerosol mass spectrometer (AMS), and physical and optical properties of individual refractory black carbon (rBC) particles were characterised using a single particle soot photometer (SP2). A Dekati dilutor was deployed before the inlet of the AMS and SP2. The number concentrations and size distribution in PM1 were measured by Fast Particle Spectrometer DMS500 and filter samples for gravimetric analysis were taken. Trace gases, flows, mass consumption and temperature were also simultaneously measured using a variety of instruments. Results obtained showed that the number size distribution and chemical compositions of emitted aerosols largely depend on the burn conditions and phases. The burning phases are identified using the modified combustion efficiency (CO_2 / ($CO+CO_2$)) and temperature in the flue. Over 80% of the BC was emitted during the flaming phase and OM dominated during the pyrolysis, smouldering and poor-burning phases depending on the fuel which was burned. The relative contribution of OM and BC in different phases rely significantly on the oxygen availability and fuel conditions such as volatility content. It is the first time that the mixing state of the OM and BC components, which has been pointed out to have impacts on climate warming and air quality, has been characterized for these sources.

16:50-17:10 – Gordon Andrews
Particle size distribution as a function of time during pine wood combustion on a cone calorimeter

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There is current interest in the impact of particles in fire smoke on the toxic hazards in fires and on the health of fire fighters. The exposure of people in fires to PM is over 1000 times that in ambient air and the role of breathing high PM in fires in fire deaths and impairment of escape from fires is unknown, as there are very few measurements of particle mass and size in fires. The exposure period would typically be 30 minutes and longer for fire fighters.

The cone calorimeter is a standard piece of laboratory fire test equipment for heat release and smoke production measurements, by obscuration. It has been adapted by the authors to enable the measurement of toxic gas species using a heated Gasmet FTIR. This was used alongside the Cambustion DMS500 particle size equipment to determine the particle size distribution. The FTIR measurements were made on the raw gas emissions from the chimney from the fire compartment and the DMS500 measurements were on the diluted exhaust on the cone calorimeter. The experiments were carried out with an air box around the test specimen to simulate a compartment fire with a fixed ventilation rate. The ventilation rate used simulated an air starved fire typical of the conditions in a modern energy efficient house. The cone calorimeter was operated at 35 MW/m^2 radiant flux and the ignition delay was 29s. The HRR was 90 kW/m^2 throughout the flaming combustion period. The combustion conditions were very rich with high CO and aldehyde emissions. The cone calorimeter dilutes the products from the chimney of the fire using ambient air and the dilution ratio was about 100 at the particulate measurement point.

The particle size distribution showed a classic nuclei and cumulative mode distribution with the nuclei peak at 20nm and the cumulative mode peak at 200nm. There was a high 20nm peak during the ignition delay, indicating a vaporised aerosol of high MW compounds from the wood, which were analysed using the FTIR. 20nm Particles continued to be produced 1 x 10^{11}/cc for the 1400s burning period of the pine wood samples and continued to be produced in the char burning phase. The 200nm cumulative mode particles were produced at 1 x 10^{9}/cc throughout the flaming combustion and then fell to <1 x 10^{8}/cc in the smouldering phase of the fire. The size distributions were quite different than those from biomass wood stoves and from modern diesels engines, although they had some similarity with old dirty diesels of the 1980s.

The FTIR analysis showed a large peak in CO (4%) and THC (6%) at around 800 – 1200 s in the fire. There was no equivalent dramatic change in the particle number in this time period, other than a small fall in the number of 20nm particles and rise in the number of 200nm particles. This work shows that fine particle emissions are likely to be a strong health effect in fires, as they are much higher than in diesel exhausts.

Poster 1.01 – Chung Ting Lao
Modelling secondary particulate emission from diesel particulate filters

Chung Ting Lao[1]*, Jethro Akroyd[1], Markus Kraft[1,2]

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Diesel particulate filters (DPFs) are an essential exhaust after-treatment control technology for diesel engines, and are required to comply with emission standards for particulate emissions. DPFs work by trapping particulate emissions in a porous substrate. Eventually, the particulate material clogs the DPF, resulting in an increase in backpressure on the engine and a reduction in engine efficiency. In order to maintain engine performance, the DPF must be regenerated by oxidising the soot that is contained within the particulates trapped in the filter. It has been observed in experiments that significant nano-sized soot particles are released during regeneration. This secondary emission phenomenon can potentially lead to a violation of the particle number (PN) emission limit set by EU in 2011.
Most existing literature models focus on the particle filtration process. The modelling of the regeneration is cruder than for filtration; it is often assumed that regeneration completely oxidises the trapped particles. However the emission of tiny particles cannot be explained by this approach. In order to predict the level of secondary nanoparticle emissions during the regeneration of a DPF, a model which solves the chemistry, temperature profile, pressure drop and the particle size distribution is proposed. The unit collector filtration model is coupled with a sectional population balance model to describe the evolution of the soot particle population during regeneration, including oxidation-induced fragmentation. The ability to predict the pressure drop and filtration behaviour is validated against experimental data. Furthermore, the possibility to describe secondary particle emission of the model is demonstrated.

Poster 1.02 – Colin Baker
Continuous Emissions and Flow Monitoring for Industrial Processes

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PCME is a leading specialist in the design, development, manufacture and supply of compliance measurement instruments and filter performance monitors for industrial processes.

We have developed a full range of dust measurement techniques which have proven to be the basis of innovative, reliable, accurate and traceable instruments for continuous particulate emission measurement.

In this poster we will discuss the various techniques developed for continuous emissions monitoring in industrial stacks including probe electrification, opacity, and light scattering for measuring particulate concentration and ultrasonic measurement of stack flow. The strengths and merits of the techniques will be discussed along with the challenging conditions that the instruments need to withstand. These include a unique solution to the growing number of challenging applications for wet stack measurement of dust concentration. By efficiently evaporating any water droplets or vapour in a continuously taken sample of flue gas, reliable and accurate dust concentration measurement can be made in stacks after wet flue gas desulphurisation (FSD) plant or wet scrubber systems. Thereby allowing dust concentration to be measured by a unique patented laser scatter technique without interference from water.

Poster 1.03 – Vignelles D.
Evaluation of the miniature particle counter LOAC for the survey of stratospheric aerosols with meteorological balloons

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The study of the stratospheric aerosols is important to our understanding of the terrestrial radiative budget. Aerosols play also an important role on heterogeneous chemistry in stratosphere. Our current comprehension of the different types of stratospheric particles and their spatial and temporal distribution is incomplete.

In the present study, we try to show that measuring particle concentrations by the means of a new balloon-borne miniature particle counter, the LOAC, may allow us to determine the local variability in stratospheric aerosols in the size range 0.2-100 µm in diameter. In that respect, the PhD thesis sums up here consists of a first phase of a more accurate characterisation of the LOAC's performance under balloon-borne measurement. A second phase consists of comparative analysis of stratospheric aerosol content based on a LOAC dataset obtained during a continuous campaign of balloon launches in France, and along with some occasional flights abroad under particular circumstances (volcanic eruption (Iceland, Réunion Island), monsoon (India)). Thus we show that the LOAC has a detection limit that restricts the measurement of submicronic particles in volcanic Quiescent periods for concentration lower than 1 particle per cm^3. Comparisons with satellites data (OSIRIS, OMPS, CALIOP), ground based lidar (LIO3s lidar OHP) and outputs from WACCM-CARMA model over the France reveal that LOAC data are more dispersed around other dataset until 25 km in altitude where the LOAC results seem converge to the detection limit.

Poster 1.04 – Dmitriy V. Kornilin
Method and device for efficiency estimation of abrasive cleaning tool

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Abrasive cleaning is widely used for various purposes in aerospace, oil industry, architecture and others. The most effective abrasive cleaning tools are based on small supersonic rocket engines with sand particles added as the working body. The effectiveness of such tools depends on the energy of the particles inside gas flow or their momentum. The determination of the momentum of the particle is the way to optimize and control important parameters of abrasive cleaning tool like the flow rate of oxygen and fuel, the diameter of the output cone and others. Existing tools based on the particle image velocimetry (PIV) method are expensive and usually focus on optionally information about particle track distribution in a flow. They are also not portable. In this paper we describe the method, tool and results of particle velocity and diameter measurement obtained at the output of the engine in order to estimate particle momentum.

Proposed method is based on the assumption that the velocity of a particle can be measured using electric pulse formed by the particle at the output of the measuring circuit. The amplitude of the pulse relates to the diameter of the particle.

Proposed tool consists of the photodiode and light emitting diode (LED) mounted on the opposite sides of the special ring placed at the output of the engine and the electronic circuit. Electronics contains current-to-voltage transimpedance amplifier, analog-to-digital converter and a DSP processor. Electronic circuit should be able measure relatively short pulses (about 1 microsecond) produced by the particles moving with velocities up to 1000 m/s. Diameters of particles to be measured are typically in range from 100 micrometres up to 1000 micrometres. The information from the tool is displayed on the laptop as the distribution of particle sizes and particle velocities obtained during the cleaning process.

In our experiments we used air flow and burning gas. Maximum velocity of particles was as high as 300 meter per second; it was reached in the experiment with propan torch. The average velocity in an air flow was approximately 50 m/s and for burning gas - roughly 100 m/s. Mean particle diameter was 450 micrometres.

The results obtained can be considered as the proof of the proposed method and tool for the estimation of particle momentum of the abrasive cleaning tool. Proposed tool can also be included into control systems of the abrasive cleaning tool as the measuring part.

Poster 1.05 – Hamish Nash
Catalytic Stripper Solid Particle Penetration and Semi-Volatile Removal Characteristics

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The poster shows the design process of a catalytic stripper (CS) which will remove semi volatiles in order to allow the measurement of solid particles down to 10 nm as part of the PEMS4Nano project. This has involved measuring the characteristics of current and prototype CS designs. In particular, the solid particle penetration as a function of mobility diameter was measured and constants created for a fitting function, used to set a benchmark for improvements to future designs. Additionally, particle and gas phase semi volatile measurements were tested and all the CSs were found to meet the PEMS4Nano requirement of removing 10^4 particles cm^{-3} at 30 nm diameter. Further, in order to test removal and penetration efficiencies, the flow rate will be varied, changing the residence time of particles within the catalyst to create the same effect as changing the catalyst bed length. In order to determine whether the catalyst was still effective at different flow rates, the temperature of the catalyst vs flow rate was measured and it was found that the catalyst could maintain temperature up to 2 SLPM flow rate, which will allow a large range of catalyst bed length testing.

Poster 1.06 – Jochen A.H. Dreyer
Experimental study of soot evolution in vapour-fed co-flow diffusion flames

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Laminar flames are ideal to study the fundamentals of soot formation due to the well-defined combustion conditions and feasibility to compare theoretical models with experimental results. Despite the extensive study of soot formation in flames there is still a lack of understanding in some fundamental processes, especially at the early stages of soot nucleation. Some reasons are challenges in obtaining accurate and reliable experimental results at such small time and length scales and the complex composition and morphology of soot. Optical techniques reach their limitations due to the reportedly amorphous, liquid-like structure of nascent soot. Nascent soot exhibits sizes of a few nanometres and might possess an electric charge, complicating its characterisation with differential mobility analysis (DMA). Other examples of experimental challenges are flame disturbance with intrusive instruments and thermocouple temperature reduction due to soot deposition.

In this work, we present experimental results obtained from a newly developed and purpose build vapour-fed laminar diffusion flame setup. The liquid fuel delivery and evaporation system enabled us to study fuels regularly encountered in real combustion processes. A new soot sampling probe design was used to record the soot spatial particle size distribution and number density *in-situ* inside the flame with a particle analyser while minimising the flame disturbance. Simultaneously, soot samples were collected on substrates for further analysis by optical and microscopic techniques to obtain a direct comparison between different methods of particle sizing and the correlation between soot size, maturity, and its optical properties. Besides, the flame temperature was measured while accounting for the increase in thermocouple emissivity and size upon soot deposition. The temporal temperature change was utilised to calculate the soot volume fraction as a reference to the number density measured with the particle analyser. The results will assist us in elucidating the fundamentals of soot formation and to benchmark theoretical models against experiments results.

Poster 1.07 – Meisam Babaie
Particle Emissions of a Diesel Car during Real World Urban Driving

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Although diesel engine has high efficiency and less greenhouse gas emission compering to petrol engine, they emits more NOx and diesel particulate matter (DPM). DPMs depending on their sizes, can pass through all the respiratory system and enter blood stream and travel inside the body which can cause serious health side effects. Carbon monoxide, carbon dioxide, nitric oxide/nitrogen dioxide, hydrocarbons and Particle mass have been monitored in different emission standards and Particle number (PN) is added to standards recently.
Portable Emission Measurement System (PEMS) have been proven for certain applications to better identify actual performance of vehicles than standard laboratory measurements. PEMS are designed in last few years to measure emissions during the actual use of an internal combustion engine vehicle or equipment in its regular daily operation under real-world conditions. Furthermore, PEMS are a cost effective solution to perform in-service testing of heavy-duty engines. Rather than extracting the engines from the vehicles and then installing them on an engine dynamometer to run their official regulatory cycles, the vehicles are equipped with on-board emission measurement systems and tested during their real in-use operation.

A standard route has been designed to investigate the particle emissions of a diesel car during urban driving in real world condition. Pegasor Mi3 is used to collect the PM data while OBD data is also considered for engine performance. The results have shown how much PM emission vary with driving conditions. An increase in car speed (corresponds to engine torque increase) shows a corresponding increase in emissions. Also, the repeated stop and starts condition resulted in considerable increased in PM emissions.

Poster 1.08 – Roger Teoh
Aircraft Black Carbon Particle Number Emissions – New Predictive Method & Uncertainty Analysis

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Black Carbon (BC) particle number emissions from aircraft jet engines contribute not only to anthropogenic climate change, but also on the deterioration of human health. The largest uncertainty in evaluations of civil aviation's impact on the climate is the contribution of BC particles to the formation of contrails, which have a significant and short-lived climate impact. Previous studies have shown that the number of contrail ice particles is strongly correlated with the number of BC particles emitted by aircraft engines.

At present, existing methods to estimate the BC particle number emissions index (EI_n), the number of BC particles per kg of fuel, are limited by several assumptions, including that BC aggregate morphologies remain constant irrespective of thrust settings. Using a bottom-up approach based on fractal aggregate theories, this paper proposes a new method to estimate EI_n for global civil aviation.

BC EI_n estimates calculated using this new approach have been validated and agree well with direct measurements from both ground and cruise conditions. A review of its model input parameters such as different BC mass emissions (EI_m) methodologies available, Geometric Mean Diameter (GMD), and Geometric Standard Deviation (GSD) have also been conducted prior to performing an uncertainty and sensitivity analysis.

The new BC EI_n predictive model is subsequently applied to an aircraft activity sample dataset from the Aviation Environmental Design Tool (AEDT). This subset consists of 3371 individual flights during cruise, which parameters are mainly captured by the US FAA radar coverage from the 9^{th} to 11^{th} of March 2006. Preliminary analysis suggests the average BC EI_n to be around $1.2x10^{15}$ #/kg-fuel, around 85% higher than previous estimates.

This higher number of estimated BC EI_n in the baseline scenario implies a smaller contrail ice particle diameter, potentially increasing its optical depth and radiative forcing. Several topics are identified for further research.

Poster 1.09 – Thomas Whitney
Design and Testing of a Wireless Sensor Platform for On-road Measurement of Emissions and Energy Use

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In order to fully understand and model the energy usage and emissions of the millions of various models of personal vehicles, lorries, vans, and utility vehicles on our roadways; methods must be developed to monitor the energy usage and emissions in a standardized manner. Methods of data collection, such as Portable Emissions Measurement Systems (PEMS), only monitor vehicle emissions and are not widely deployed due to their cost. Thus, there is a need for a low-cost, standardized sensor package for the collection of emissions and energy data. This data will enable detailed modeling of individual vehicle energy use and emissions that can be scaled to predict the emissions of the transportation sector at the street, neighborhood, city, or even national scale.

Poster 1.10 – Yanlong Wu, Hu Li
Comparison of PN measurements from emissions of a miniature combustion aerosol standard soot generator

Yanlong Wu, Hu Li *, Karl Ropkins, Richard Barrett & Christopher Whiteside[2], Gordon Andrews,[1]

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Due to its negative impacts on ecosystem and human health, particle emissions from combustion engines become a popular topic. An important question is the accurate measurement of particle numbers and their size distributions due to the difficulties in getting reliable and repeatable measurements from different instruments and dilution settings. This paper presents the comparison of PN (Particle Number) measurement results from five PN instruments with different sampling frequency and various dilution settings. The particles were generated from a miniature combustion aerosol standard (Mini-CAST) soot generator using propane as fuel which was able to provide different particle concentrations. The compared instruments include DMS500 MK II tested with three sampling frequency settings (1Hz, 5Hz and 10Hz), two HORIBA MEXA 2300 SPCSs connected with two different dilution systems, one TSI3080 SMPS, and one AVL 483 micro soot sensor measurement unit tested with varying dilution settings including zero dilution. In order to bring the most reliable datum for comparison, five separated sampling points were made available on the exhaust pipe of the Mini-CAST soot generator which allow all the instruments to measure simultaneously with exactly the same exhaust. The aim of this research is to investigate the differences of five PN instruments and to find out correlation between different instruments. The impacts of sampling frequency and dilution ratio settings on PN measurements were investigated. The results obtained will provide better understanding of PN detection and support the future PN measurement instrumentation and methodology development. The results will also provide information to the legislation on diesel particle numbers.

Poster 1.12 – H. Mat Kiah
Particle size emissions from PVC electrical cable fires

Miss H. Mat Kiah*, Bintu Mustafa, G.E. Andrews, H.N. Phylaktou, Hu Li

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Electrical cables are in every building and form a significant part of fire loads and can through electrical faults be the first item burnt in some fires. PVC insulated cables are still quite common in buildings and this work investigates Prysmian PVC cables. Deaths and injuries in fires are dominated by the influence of toxic smoke emissions and most of the work on the hazards of smoke are concerned with the toxic gases such as CO. However, fires are large producers of particulate material at levels over 1000 times that in controlled combustion and there is little knowledge of the role of ultra-fine particles in fires and none at all for electrical cable fires.

The cone calorimeter fire material testing equipment was used in the present work, which is an ideal test procedure for particle size measurement, as controlled dilution (100/1) of the fire products occurs which enabled diluted samples to be used for particulate number measurement. The Cambustion DMS500 transient particle size analyser was used to determine the particle size distribution. The cone calorimeter uses a 100mm square test specimen and this was filled with 10 100mm lengths of the PVC cable. The test specimen was on a load cell so that the mass burn rate was determined. The cone calorimeter ignites the specimen using a conical electrical heater that is calibrated to achieve a control radiant heat flux on the test specimen, which was 35 kW/m2 in the present work. The fire occurred in a restricted air supply with an insulated air box around the 100mm square test fire. A chimney on the conical heater exit was used to obtain a raw gas sample for toxic gas analysis using a heated Gasmet FTIR. For gases dilution is undesirable as oxidation of the toxic gases may occur. For particles the chimney temperature was too low for carbon oxidation to be significant. The dilution process also condenses unburned hydrocarbons and carbonyl species, which may form nano aerosols and these may be the source of the 10nm particles measured in the present work. HCl is a major product of PVC fires and hence hydrochloric acid aerosols are likely in the particulate measurements. In previous work of the authors, PVC cable fires were investigated with free ventilation and HCl yields of about 50% were measured with Acrolein at 5% yield and Formaldyhyde at 3%. Thus there are plenty of liquid aerosol possible in the diluted products of PVC fires.

The results showed a large nuclei number peak at about 10nm. The coarse particle peak only started after flaming combustion occurred and this was initially at 200nm, which increased to 300nm after 1000s. The 10nm peak was high for the first 200s, then dropped dramatically and slowly reformed later in the fire and at the end of the fire was very high with a low coarse particle peak. The FTIR gas species will be used to speculate on the likely composition of the nano-aerosols as a function of time in the fire.

Poster 2.01 – Astrid Boje
Computational study of temperature effects in TiO2 synthesis in an industrial reactor

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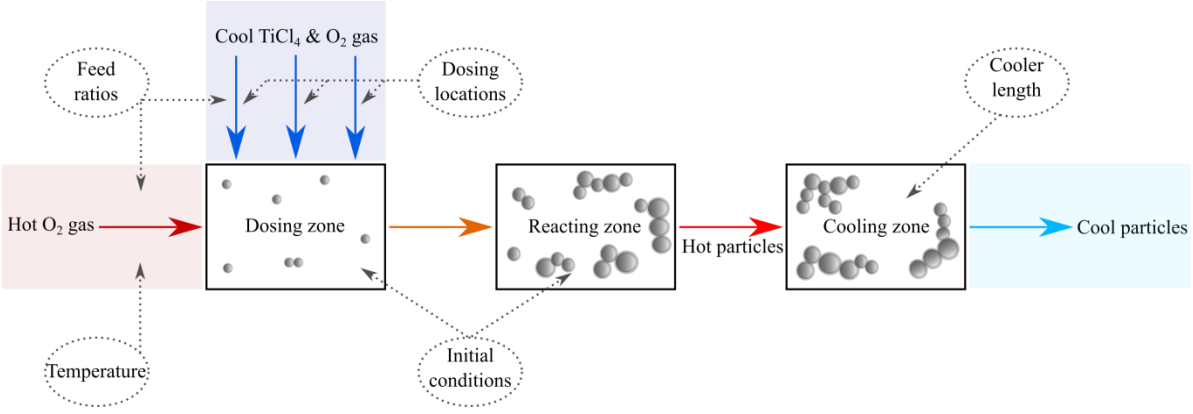
A detailed particle population balance model is used to investigate temperature effects in the industrial gas-phase synthesis of pigmentary titania. An energy balance replaces the imposed temperature profile used in previous work. The temperatures of both phases are tracked during the gas-phase reactions and particle processes, and heat transfer is incorporated using the particle surface area (available due to the level of detail included in the particle model) for exchange. A network of ideal reactors is used to describe local features of the composition and flow in the dosing, reacting and cooling zones of the reactor.

It is important to control temperature in the industrial process to achieve high conversion of the precursor while minimising energy intensive post-processing and avoiding potentially dangerous runaway. Particle size and morphology are functions of temperature-dependent particle processes and significant aggregation and sintering are undesirable in the pigment process. In the industrial reactor, cool titanium tetrachloride in oxygen is injected through the walls at several dosage points into a stream of hot oxygen. This maintains temperature in the dosing zone, and determines the developed exotherm profile in the reactor. A cooling stage is required to reduce temperature and curb excessive growth.

Design and operation of the reactor requires careful consideration of factors that influence the temperature profile such as the hot oxygen temperature, the ratio of hot and cool volumetric inflow rates, the ratio of oxygen to titanium tetrachloride in the injections, the number and location of injections, the reactor length and the cooling profile. This work involves computational exploration of the effects of such factors towards informing operation of the industrial process to produce a suitable pigmentary product. A parameter study is performed to compare the particle morphology and relative particle process rates under different conditions and several expressions for the heat transfer functions are investigated.



Poster 2.03 – Carlos E. Garcia
Experimental Validation of a Silica Nanoparticle Formation Model

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A significant proportion of man-made air particulate is generated during combustion processes. Yet, the processes responsible for particle formation and their dependence on the characteristics of the flow are not fully understood. In this work, nanoparticle formation takes place during the oxidation of a silane-laden jet in a “Cabra” burner. Various laser diagnostic techniques are used as multiple validation of the LES model. The vitiated co-flow inherent to the “Cabra” geometry has the advantage of providing a controlled environment for the reaction to take place, and hydrogen is used as fuel to avoid soot formation, thus ensuring that all particles must come from silane oxidation.

At present, suitable conditions of temperature and precursor concentration that lead to particle formation have been identified for both turbulent and laminar jets. Certain correlations have been found between flow conditions and particle size.

OH-PLIF and elastic light scattering (ELS) experiments have been performed in the turbulent jet. These two techniques were successful at retrieving qualitative profiles for OH abundance and particle concentration in the jet. Additionally, Angle-Dependent Light Scattering (ADLS) is currently being employed as an alternative for in situ particle size measurement. Preliminary experimental results show the technique is suitable to measure large aggregates and simulations suggest it should be suitable to measure particles in the order of 10 nm.

Thermophoretic sampling and electron microscopy imaging was employed in both turbulent and laminar jets as an independent verification of particle size and morphology.

Future research on this system will involve SiO-PLIF to measure the abundance of the SiO radical and help validate numerical simulations currently under development at the University of Stuttgart.

Poster 2.05 – Mika Svedberg
Using a MultiCPC system to measure particle size distribution generated by a plasma lighter

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Nanoparticles generated by a plasma lighter were studied using a MultiCPC system. The target was to define the size distribution of the generated nanoparticles and to study the time scales of the particle size distribution evolution.

SUMMARY
The operation of the plasma lighter is based on ionizing air and running current through it. The lighter is normally used for lighting cigarettes etc. We collected 1 Hz data using: A11 nCNC*) with cut-off diameter at 1.3 nm and A20 CPCs with cut-offs at 2.8 nm, 5 nm and 10 nm. Remarkably high concentrations of nanoparticles were detected (> 10^5/cm3 without diluter).
Majority of the particles were below 3 nm in diameter (detected only with the A11 nCNC); the freshly emitted particles were all below 2.8 nm but in a few seconds they partially grew into larger sizes

MEASUREMENT SET-UP AND PROCEDURE
The sample was generated with the plasma lighter inside a 10 cm x 20 cm x 3.5 cm stainless steel chamber. The plasma lighter was on only for about 0.1 s. Sample mixing and initial dilution was achieved by pushing 5 lpm HEPA-filtered air through the chamber allowing excess gas to flow freely out via another HEPA-filter.
Dekati Ejector Diluter was used for part of the measurements to dilute the sample.
By combining cut-off information with the concentrations, we calculated relative concentrations of different particle size bins and detected particle growth over time.

RESULTS

- Majority of the particles were 1.3 - 3 nm.
- Even though the lighter was on for a short time and the Ejector Diluter was used (with a nominal 1:8 dilution ration) very high concentrations for small particles were detected.
- Rapid growth of nanoparticles was observed.
- All particles were initially in the smallest size range. After few seconds, particles > 10 nm started to appear.
-

*)*Airmodus A11 nCNC system uses a two stage condensation technique to detect particles as small as 1 nm in diameter. Both electrically charged and neutral clusters / particles can be detected; size distribution for 1-4 nm particles without aerosol charger or a DMA [See e.g. Vanhanen et al, 2011 or Kulmala et al. 2007]*

REFERENCES
Kulmala et al.. 2007. Journal of Aerosol Science 38 289-304
Vanhanen J. et al. 2011. Partice Size Magnifier for Nano-CN Detection. Aerosol Science and Technology, 45(4), 533-542.

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Poster 2.07 – Vilhelm Malmborg
In-situ XPS on Carbonaceous Nanoparticles

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We employ in-situ aerosol mass spectrometry for detailed chemical analysis of ambient and engineered nanoparticles. The method provides means to analyze the bulk chemical properties of nanoparticles. However, heterogeneous chemistry and ice nucleation in the atmosphere, as well as biochemical interactions in the human lung, are likely dictated by surface properties. Surface specific techniques are therefore anticipated to increase our understanding of such interactions. Pilot experiments investigating the surfaces of aerosol particles using in-situ X-ray photoelectron spectroscopy (XPS) were conducted at MAX-lab in 2015. XPS, based on the principles of the photoelectric effect, is a highly surface sensitive technique that measures electron binding energies of atoms and the small shifts in binding energies arising from different molecular bonds.

Soot particles, secondary organic aerosol (SOA) coated soot particles and pure SOA particles were included in the study. A photon energy of 360 eV was used for photoemission spectra of C1s. C1s binding energies were calibrated against the C1s of gaseous CO2 at 297.7 eV. Fresh and coated soot particles were introduced into an XPS vacuum system via an aerodynamic lens. The aerodynamic lens focuses the particle stream and removes the gas phase via differential pumping. Alignment of the particle stream and the X-ray photon beam allowed us to perform the XPS analysis with adequate signal.

Our results show that oxygenated organic molecules shifted the C1s to higher binding energies. In conclusion, we have successfully implemented synchrotron-based in-situ XPS to probe carbon in aerosol particle surfaces and gas phase. The results of this study are encouraging, and the possibilities to further improve the method for in-situ aerosol surface characterization are many.

Poster 2.08 – Manoel Y. Manuputty
Aggregate formation in stagnation flame synthesis of TiO_2: A modelling and experimental investigation

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Titanium dioxide (TiO_2) nanoparticle is one of the most studied materials for its wide-ranging applications with high commercial importance including photocatalysis and solar cells. The properties of nanoparticles, such as size, crystallinity, and morphology, have been shown to be critical for these applications. In its application as photocatalyst, for example, the overall performance of TiO_2 is influenced by the extent of aggregation as the interface between particles can facilitate charge separation. Aggregation is also expected to play an important role in anatase-rutile transformation as the interface between two primary particles serves as nucleation point. Formation of aggregates consisting of smaller primary particles is commonly observed in nanoparticle synthesis, a result of collision between particles followed by sintering process. In this study, the aggregate formation is studied by comparing the experimental results with model predictions. A stagnation flame burner is used as it allows for investigation of aggregate formation in the early stage of TiO_2 growth (sub-10 nm size) due to very short residence time. The extent of aggregation varies as function of operating conditions such as precursor loading and equivalence ratio. The flame is modelled with one-dimensional stagnation flow approximation coupled with method of moments with interpolative closure. The simulation results are then postprocessed with stochastic population balance model to resolve for individual primary particles and their connection to other primary particles in an aggregate. The comparison gives insight to the relative importance of particle processes including surface growth, coagulation, and sintering.