

Winter - Spring 2004-2005 Issue

The Institute of Physics
COMBUSTION PHYSICS GROUP NEWSLETTER
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1. COMBUSTION PHYSICS GROUP

Web site: <http://groups.iop.org/CB/>

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2. EDITOR'S CORNER

I am very happy to bring this Newsletter to you, albeit a little late. It includes a range of information on combustion and combustion-related meetings that you may find interesting.

Once again I remind you that unsolicited articles, conference reviews etc are very welcome for the Newsletter. Please email them to the Assistant Editor, E. Mastorakos (em257@eng.cam.ac.uk). A sum of £50 is available for articles by *bonafide* research students and young researchers (including those working in industry) on topics connected with combustion. Supervisors, please encourage your students to write one! In addition it would be nice to have articles by retired members on their thoughts and reminiscences of working in combustion in the past – difficulties encountered, meeting scientists, historical perspectives on research laboratories - the list is almost endless. If anyone has any ideas for articles, I would be very pleased to hear from them.

Mostly thanks to Phil Bowen and his colleagues, we also have a new Website that you **must** visit. It includes announcements for conferences, travel grants and other useful information and we will make every effort to keep it updated. The URL is: <http://groups.iop.org/CB/>

Phil Cadman, Editor
Epaminondas Mastorakos, Assistant Editor
June 2005

3. MEETINGS AND CONFERENCES

3.1 Past

The **Spring 2004 Meeting of the Combustion Institute (British Section)** was held at Shell Thornton on 19 April 2004 and had “**Sustainable Combustion**” as its topic. Speakers from Shell, Leeds, Birmingham, Ulster and Cardiff covered topics from coal utilisation to alternative fuels, biomass, hydrogen production, and fuel cells. A report can be found from <http://www.combustion.org.uk>

The 30th International Symposium on Combustion took place July 25th – 30th 2004 in Chicago at the University of Illinois. A report from a post-doctoral researcher who attended following a travel grant by the IoP Combustion Physics group is included in this Newsletter. In general, the Symposium was a great success, covering most topics of combustion. About 340 papers were accepted from about 750 submissions. The reviewing process was, as usual, very rigorous and justifies the official classification of the Proceedings as a journal. Video recordings and presentation slides of the plenary talks are available on-line from: <http://www.uic.edu/eng/ems/Combustion/>

A special meeting to honour Prof. Ken Bray’s 75th birthday was held at Cranfield on 17 September 2004 on “**Advanced Combustion Modelling**”. Distinguished speakers from around the world gave plenary talks, while shorter presentations were given by members of the EPSRC-funded Network COCCFEA, which brings together UK groups specialising in combustion simulations.

The **Autumn 2004 Meeting of the Combustion Institute (British Section)** took place in Cambridge on 20 September 2004 and focused on “**Particles in Flames**”. A range of talks were given covering the generation and measurement of nano-particles, soot formation and prediction methods for soot in turbulent flames. A detailed report can be found from <http://www.combustion.org.uk>

Our own **IoP Combustion Physics Group Meeting** on “**Combustion Generated Noise**” was held at the Institute of Physics Headquarters in London on 27 September 2004. A series of talks from universities and industry were given on combustion-induced oscillations, unsteady combustion, and engine noise in cars. A detailed report is included in Section 3.3.

Our own **IoP Combustion Physics Group Meeting** on “**Fuels for the Future**” took place on 14 April 2005 at Cardiff University. We have two extensive reports on this special meeting in this Newsletter in Section 3.3.

The Second European Combustion Meeting (ECM2005) took place in Louvain-la-Neuve in 3-6 April 2005. The successful format of the 2003 Meeting was followed, where a few plenary lectures were followed by poster presentations. This gave the opportunity for quite numerous and detailed interactions between the participants, assisted significantly by the large number of nearby cafés and restaurants! The full papers were distributed on a CD-ROM. The next meeting will be hosted by the Greek Section in 2007, probably in beautiful Chania in Crete.

The Spring 2005 Meeting of the Combustion Institute (British Section) took place in April 18/19 in Edinburgh in honour of Prof. D. Drysdale on his retirement. The topic was “**Trends in Fire Research**” and more information can be obtained from Dr. Jose Torero (j.torero@ed.ac.uk).

3.2 Future

An extensive list can be found at: <http://www.combustoinstitute.org/conferences.htm>
<http://www.combustion.org.uk>

We are co-sponsoring the 1-day Seminar organized by the Institution of Mechanical Engineers “**An Engineer in Court**”. The seminar aims to help engineers understand the best practice in keeping records and what to do if asked to go to court. For further information, see: www.imeche.org.uk/conferencesandevents/court

The Autumn 2005 Meeting of the Combustion Institute (British Section) will take place in New Hall College at Cambridge on 13 September 2005. The focus is on **“Dilute Combustion”** and information can be obtained from Prof. S. Hochgreb (sh372@eng.cam.ac.uk). This meeting is co-sponsored by the IoP Combustion Group.

The **final meeting** of the EPSRC-funded Computational Combustion network **COCCFEA** will take place in Fitzwilliam College at Cambridge on 19-20 September 2005. There will be international invited experts and UK-based speakers to review the advances and challenges of **computational combustion**. Information from Prof. Kai Luo (K.H.Luo@soton.ac.uk).

Our very successful annual event aimed at **Young Researchers** will take place in Loughborough on the 21st of September 2005. This year the event is co-sponsored by the Combustion Institute. The best poster presentation from academia will receive a prize funded by EPSRC, while the best contribution to industrial research will receive a prize sponsored by British Flame. Further details will be announced shortly, so keep looking at our Web site (<http://groups.iop.org/CB/>) or contact Drs. Peter Cumber (P.S.Cumber@hw.ac.uk) or Ralph Boyce (Ralph.boyce@rolls-royce.com).

The **Fourth Mediterranean Combustion Symposium** will attract most European combustion researchers to Lisbon in October 6-10 2005. Further information can be obtained from Dr. Federico Bereta (beretta@irc.cnr.it).

Our **Combustion Physics Group Spring Meeting** will take place in April 2006 and the topic is **“Electrostatics and Combustion”**. Further details will be uploaded on our Web site. Organizer: Dr. Jeff Allen (jeff@scion-sprays.co.uk).

The **31st International Symposium on Combustion** will take place in Heidelberg between 6 and 11 of August 2006. Details from <http://combustion2006.org>. We remind our readers to expect tough competition and a deadline for a paper in early December.

3.3 Detailed reports on meetings

Combustion Generated Noise

Autumn meeting of the IOP Combustion group held on 27 September 2004 at London.

A one-day meeting on "Combustion Generated Noise" was held at the IoP Headquarters in London on 27 September 2004. The meeting was organised by Dr. Phil Bowen of Cardiff University, on behalf of the IOP Combustion Group. Around 50 delegates from various academic institutions and industries in UK attended the meeting. The registration for the meeting started at 10.00 on that sunny day. After informal introductions and chat with warm coffee, the meeting started sharply at 10.30 am. There were nine talks covering different aspects of combustion generated noise with industrial as well as academic perspective.

The first technical presentation was by Mr. Stuart James, E. ON, UK, on “Safe & Flexible Operation of Modern Industrial Gas Turbines”. The focus of the talk was on the problems caused by combustion dynamics on the generators and the E. ON’s solution methodology. The combustion control of instability by asymmetry in Fuel/oxidiser ratios on the annular arrangement of combustors was presented as one of the company’s successful solution methods. He also elaborated the role of an on-line combustion monitoring system in detection of combustion dynamics.

Dr. Alex Riley from Cambridge University, presented some experimental and theoretical work on “control and prediction of self-excited oscillations”, carried out at Department of Engineering. In the first part of this talk, the use of linear model together with the experimental transfer functions between the inlet flow velocity and the heat release fluctuations in the flame was presented. During the next part, he dealt with the successful active control of pressure oscillations using model bases self-tuning regulator. “The Effect of pressure oscillations on structure of the recirculation zone in confined swirling flames” was the third talk, presented by Dr. James Dawson of Cambridge University. He presented the experimental work he performed while he was at Cardiff University on cycle-resolved velocity measurements in practical combustors configurations. The dynamic response of the

recirculation zone and their relevance to thermo-acoustic instability was the main thrust for this presentation.

Prof Chris Lawn of Queen Mary & West field presented his recent theoretical model for flame transfer function and compared his model with experiments on a small-scale swirl burner. His talk included introduction to the fundamentals of his modelling approach and on various parameters of the transfer function.

The last talk for the morning session was by Prof. Andy McIntosh of University of Leeds on an interesting study on explosive discharge of the bombardier beetle. With numerical studies to backup the advantages of naturally occurring design of the combustion chamber and nozzle system was presented and the possibility of application in gas turbine relight was also suggested. After that lunch, the meeting resumed at 2.00pm. The first talk in the afternoon session was by Greg Sims on involvement of QinetiQ in combustion noise. He exchanged the company's experience in transfer function measurements, passive acoustic damping and active control methods.

The measurements of air fuel ratio (AFR) in spray injectors and their response to acoustic forcing using planar laser induced fluorescence, Mie scattering and Laser sheet drop sizing (LSD) was presented by Dr. Mark Jermy of Cranfield University and reported a positive correlation between the acoustics and AFR and measured Sauter mean diameter. After this talk, I presented my experimental work on response of fully premixed flames to imposed inlet velocity oscillations. The main thrust of my talk was in comparison of different measurement techniques: Chemiluminescence and laser based techniques (Flame surface density from OH PLIF and heat release from simultaneous OH and formaldehyde PLIF) in the context of their application to combustion instability research and I also highlighted the origin of saturation in response in premixed flames.

The talks up to then were mostly relevant to the gas turbine environment, the next talk, which was the last on the day was by Mr. Chris Carlson on combustion noise within the automotive industry. With introduction to combustion noise relevant to High Speed Direct Injection diesel engines, he presented the tools used and developed at Ricardo to access combustion noise.

After the talk, there was a half hour discussion on directions of UK research in combustion research and the relevance to practical problems, after which all the delegates gathered to have a wonderful post presentation discussion. Though every presentation had 5 minutes of question time at the end, the one-to-one discussion was very useful to discuss the interesting/particular issues in detail. As a student I found the meeting very useful, since I managed to have good interaction both academics from university and experts from industries. I also made a quite number of friends who study in other university and we exchanged useful information about our work. The comments I obtained during the meeting from the delegates were very valuable which I incorporated when I prepared the manuscript on the work for a journal publication. Thanks to IOP Combustion Group for organising the meeting.

Dr. Ramanarayanan Balachandran

Department of Engineering
University of Cambridge
Trumpington Street
Cambridge CB2 1PZ

30th International Symposium on Combustion

July 25-30 2004

Chicago, Illinois, USA

From July 25-30, 2004 , I was privileged to attend the 30th International Symposium on Combustion hosted by the Combustion Institute and the University of Illinois at Chicago. It was a great experience to once again meet and interact with researchers from around the world working on all the various aspects related to combustion science. On the first afternoon there was a welcome reception allowing us to meet both old and new combustion friends. The following days consisted of an opening 50th Anniversary Lecture, followed by presentations divided up into 7 parallel sessions. In the breaks in between, one could enjoy and engage in the discussion around the posters in the Work-In-Progress (WIP) poster session. We were also hosted to a series of social events including a picnic at the Navy Pier allowing us to appreciate the Chicago skyline, and a fine banquet at The Fairmont Hotel at which the awards from the Combustion Institute as usual were announced. In the following report, I have tried to sort the presentations into sections according to various disciplines, following the conference format

as far as possible. As there were many parallel sessions, I will make a selection of some of the sessions and try to emphasise the state of the art within these fields. However, I will begin with the four plenary lectures, the 50th Anniversary Lectures.

50th Anniversary Lectures

The 50th Anniversary Lectures were meant to address the general topics of combustion science and state the achievements and challenges within the field. The lectures were on the topics of combustion theory and modelling, problems in turbulent combustion research, experiments and in particular laser diagnostics and chemical mechanism development. The conference opened with a presentation by Prof. Forman Williams (UCSD, USA) on the accomplishments of theory in combustion science. He was the lecturer of the paper jointly prepared by several of the most well renowned theoreticians in the field. Prof. Williams accounted for the developments using advancing mathematical methods in modelling. However, he also addressed the new possibilities that lie in numerical modelling and use of more powerful computers. The second 50th Anniversary lecture was devoted to problems related to turbulent combustion modelling and was presented by Prof. Robert Bilger (Sidney, Australia). He addressed the success of advancing mixing models, such as the CMC model, to which he has contributed significantly. Also, he discussed the successful applications of these models in real engine development, and he mentioned the high performance engines from Ferrari as an example. It was a slight disappointment that he chose not to discuss premixed turbulent combustion modelling and challenges within this field. The achievements and the developments of new experimental techniques was the topic of the third 50th Anniversary lecture held by Prof. K. Kohse-Hoinghaus (Bielefeld, Germany). She started her presentation with the demonstration of the simplest experimental objective – a laminar flame. However, the presentation was focusing on the development within the laser diagnostics as a measuring tool for more complex combustion systems, and she emphasised the importance of selecting the right chemical parameters for study, even in parallel with parameters describing the flow field. The final 50th Anniversary lecture was held by Prof. J. Troe (Göttingen, Germany) on the achievements and challenges within chemical mechanism development. He chose to be quite detailed in his description of the challenges, and argued that only then could he reveal the real problems the developers faced when for example determining whether a reaction path favours the one direction or the other. He also mentioned the achievements made by employing quantum chemistry when describing a reaction path. It was then possible to describe the reorganisations within the molecules that is thought to be responsible for the appear ant favouring of reactions paths not predicted by standard theory.

Turbulent combustion

The field of turbulent combustion consists of several disciplines including for example turbulent non-premixed flames, autoignition in turbulent mixtures, and premixed turbulent combustion. A series of sessions were devoted to these topics both from a theoretical and experimental point of view. Concerning theory, my overall impression is that since the modelling is difficult, often very simple fuels like hydrogen are chosen for the simulations in order to emphasis on the flow field as efficiently as possible. However, several techniques to handle more complex fuels were presented. For example P. Lindstedt et al. (Imperial College, UK) presented good results for soot prediction using a joint-scalar transported PDF method. However, he also addressed problems and disagreements with experimental data that needs to be solved. Another approach is the use of mixing models like the flamelet model or the CMC (conditional moment closure) model. C. Hasse et al. (Aachen, Germany) presented a model based on a n-dimensional flamelet model. In this model, they account for several simultaneous mixture fractions, in his case two, applied to split ignition in DI diesel engines. This approach can be compared to the alternative double conditioning methodology for the CMC, presented by A. Kronenburg (Imperial College, UK). Also, a stochastic flamelet approach for diesel engine combustion was presented by H. Pitch et al. (Stanford, USA) which resulted in engaged discussion after the session. The sessions on turbulent combustion modelling based on large eddy simulations (LES) was initialised by J. Janicka (Darmstadt, Germany) presenting recent and ongoing work in the field. The conclusion was that the LES approach does agree well with measurements for situations where the turbulence is governed by large scale structures. However, the approach is in need of a subgrid closure, and the following presentations were focusing on various models for the closure problem. Also, using LES in premixed combustion modelling was addressed, and even described as the most promising approach in this concern.

One session was devoted to lifted turbulent flames. Here both theoretical modelling and experimental work was presented. A joint experimental work between the Technical University in Aachen, RWTH, and the American University in Cairo was presented. Joint measurements of the

multi-reaction zone and the flow field, based on laser diagnostics and planar imaging velocimetry, revealed experimentally the existence of a triple flame at the stabilization point. Other presentations were devoted to simulations of such flames either using direct numerical simulations (DNS) or models like CMC. The main objective was the prediction of lift-off heights and ignition and extinction mechanisms. An impressive piece of work on turbulent flames using DNS was presented by Y. Mizobuchi et al. (Japan Aerospace Exploration Agency & Meijo Univ., Japan). The work focused on the formation of diffusion flame islands in a turbulent hydrogen jet flame. The work was performed on a multi-processor computer consisting of over 300 processors. The time range of the simulation made it possible to explore the time dependent flame behaviour. However, some comments after the presentation pointed out uncertainties concerning their conclusions related to the chosen tolerance limits in the simulations. Effects dependent on structures smaller than the chosen tolerances will be ignored, and these uncertainties need to be addressed when dealing with numerical experiments.

Nano-Particles

In this session, the main topic was the development and structures of nano sized particles like soot in combustion. In this session the soot formation was discussed on a somewhat more quantum chemical level than the previous session on polycyclic aromatic hydrocarbons (PAH) and soot related to pollution formation. In the nano-particle session several interesting presentations addressed the problem of describing the mechanisms behind coagulation and surface growth processes. M. Frenklach et al. (Berkeley, USA) presented a new reaction pathway for the surface reactions related to a five-member ring migration process on the surface. Other presentations were devoted to Monte-Carlo simulations of soot particle coagulation and aggregation discussing the particle shapes according to primary particle size, and stochastic modelling of particle size and age distribution. In the latter, it was also investigated if particle age is correlated with surface reactivity and growth. However, there are clearly many unexplored aspects concerning soot formation and the mechanisms behind its growth and size distribution. Many interesting comments addressing the problems and unknowns in the modelling were put forward after the presentations.

Chemical Kinetics Development

The sessions on chemical kinetic mechanism development were mainly devoted to the development of detailed and more extensive mechanism for a range of different fuels. My interests lie in the field of mechanism reduction and I will therefore focus on this in the present report. Some new concepts in reduction techniques were discussed, such as the new deterministic algorithm presented by M. Kraft et al. (Cambridge, UK). In this algorithm numerical speed-up is achieved by reaction elimination but where the species itself is kept. The algorithm can be understood as a new solver method for huge chemical systems without the high restart cost which is the problem with conventional solvers. An interesting presentation was given by K. Koenig et al. (Karlsruhe, Germany) addressing the following important question: are the reduced mechanisms governed by the same reactions as the detailed mechanisms. The basis of the investigation is the intrinsic low dimensional manifold (ILDM) method developed by among others coauthor U. Maas. In order to perform the investigation, sensitivity equations were derived also for the reduced ILDM. The first outcome of the study showed that the sensitivities are in fact quite similar. S. Rigopoulos et al. (Imperial College, UK) presented a methodology called Rate-Controlled Constrained Equilibrium (RCCE). The methodology is based on finding a rate-controlled constrained equilibrium in terms of thermodynamically dependent variables acting as the constraint. The RCCE is tested for validity and found to be sufficient to well predict major species concentrations and acceptable for NO concentrations. Finally, I want to mention a methodology that possibly will become more and more popular in the future. The paper was presented by A. Tomlin (Leeds, UK) and is based on a systematic lumping procedure where similar species are "lumped" together as one during the simulations. This enables initially large chemical systems to be implemented into CFD models. The methodology does not involve creating "pseudo"-species, and the lumped species can be separated into the original species for consistency.

Dr. Terese Lovas,
Department of Engineering,
University of Cambridge, UK.

Fuels for the Future

Spring meeting of the IOP Combustion group held on 14 April 2005 in Cardiff

Report 1

The IoP Combustion Physics Group held this meeting in palatial surroundings at Cardiff University. It was co-sponsored by British Flame, the British Section of the Combustion Institute and the Welsh Energy Research Centre (WERC). It included a dinner the previous evening to present an award to Professor Felix Weinberg (FRS) in recognition of Felix's lifetime contribution to Combustion Physics research. The meeting discussed the inter-related questions of energy supply and utilisation, environmental and socio-economic issues, global climate change and UK soon to become a net importer of energy. It raised many important questions to which there are no easy answers!

The meeting started with Lars Waldheim (TPS Sweden) giving an overview of EU and UN legislation on emissions. We were given a rapid but informative tour from global warming to the UN Framework on Climate Change and the 1997 Kyoto protocol. He emphasised the magnitude of problem, especially if the only fair way is to get to the same CO₂ emission per person globally. Then, we were on to EU targets for renewables (including waste incineration), biofuels for transport, and the EU ETS (emissions trading scheme). Finally, Lars mentioned concerns about transboundary pollution, eg acidification, and the consequent UN/ECE convention.

Iftikhar Kahn (RWE npower) provided 'a generator's view of future fuels' and why we are so busy with coal/biomass co-firing. He discussed the UK Renewables Obligation and its implication for electricity generators. He described the relative environmental, technical, and cost issues related to burning biomass in dedicated only plant, in CHP plant or co-firing with coal in existing power stations. He concluded that co-firing of biomass with coal is currently the most cost-effective and efficient method of generating electricity from biomass. He discussed the factors controlling UK Energy Crops and described RWE npower's experience of biomass co-firing at its conventional coal fired power stations and what it had learnt from burn trials on its Combustion Test Facility.

After that, there was a change again of country, when Prof Khalatov ((Ukrainian Academy) gave a fascinating insight to energy problems in the newly independent Ukraine. The Ukraine is understandably proud of its independence and consequently does not like dependence on Russia for energy, eg large imports of Russian natural gas. They need their industry (cement, sugar, chemical, metallurgy etc) to become much more energy efficient. Their coal industry needs lots of money for rehabilitation. They have significant nuclear generation but have built no new nuclear capacity after Chernobyl (which was near Kiev). Options for the future include new nuclear stations as well as renewables, including biomass, wind, small hydropower, solar, geothermal. They signed Kyoto before the Russians did.

Ray Allan (Sheffield University) on the Bunsen process (not the Bunsen burner...) as a way of manufacturing H₂ large scale. In other words, he addressed the key question of how to produce the industrial-scale quantities of H₂ that the hydrogen economy will need. Likely options for H₂ production were discussed in terms of efficiency, CO₂ mitigation, land requirement and cost. Thermochemical cycles were one of the better options. He then discussed one such cycle, the Sulphur Iodine (SI) cycle or Bunsen process. A noble attempt to teach physicists some chemistry.

Kevin Kendall (Birmingham University) talked on 'towards a flame free future', and succeeded in plugging fuel cells while demonstrating various real flames and not setting off the fire detectors. A remarkable *tour de force* with the message that we must stop using flames for energy for reasons both of efficiency and emissions.

Nick Syred (Cardiff University) discussed 'biomass and H₂ potential', adopting a suitably questioning approach. He started by quoting Portuguese work related to an EU project on H₂ in buses which showed that diesel and compressed natural gas were better overall in terms of efficiency and CO₂ production than fuel cells. Fuel cells should be used on for stationary combustion. There have been biomass successes in Sweden, Finland, and Austria. All have large biomass supplies, small populations, tax breaks for Cogen and climates that mean that they need heat from biomass Cogen for a large part of the year. However, their electricity is dearer than in the UK. Co-firing coal/biomass was driven by ROCs and by the high efficiency of such systems (ie existing larger PSs). He mentioned work at Cardiff biomass for power generation, aimed at small end of market (<10 MW). He concluded that biomass was expensive as sole fuel for electricity generation, H₂ was a red herring

except from co-firing in large stationary systems and there was a need for technological innovation for small scale applications. I'm not sure if everyone agreed but it was a thought-provoking talk.

Diane Lance (Ricardo) then discussed 'future automotive fuels'. She recommended an incremental rather than evolutionary approach, such as further improvements to diesels, and some hybrids. It seems that the real challenge is trying to persuade car-buyers that they do not want larger, faster cars with more goodies and gizmos.

Greg Sims (Qinetiq) then described the implications of biofuels on GT combustor design. The main problem was lack of detailed information on combustion characteristics of possible biofuels.

Mario Graziado (ENEL) presented on 'perspective future fuels for power generation', which was an interesting alternative to a UK view given earlier in the meeting. The Italian way involves converting large oil plant to coal and increasing renewables (mainly hydro).

Brian Ricketts (UK Coal) talked about the future of coal and gave a robust defence of the UK coal industry. Apparently, the rot set in for the UK coal industry when Churchill chose oil rather than coal for WWI battleships and how it's been down hill ever since. He made some not entirely complementary remarks about UK government; for example, the UK generators still do not know what their CO₂ allowances are for this year, which makes planning difficult.

Alas, the one failing of the meeting was a failure to keep to time; I had a train to catch and so I didn't hear the last speaker. I extend my apologies. Apart from that, it was a fascinating day full of difficult but relevant questions, and our hosts at Cardiff made us very welcome.

Dr. Peter Stephenson
RWE Power International

Fuels for the Future

Spring meeting of the IOP Combustion group held on 14 April 2005 in Cardiff

Report 2

The Spring Meeting of the Institute of Physics 'Combustion Physics Group' took place in the Council Chambers of Cardiff University in April 2005. The title and theme for the meeting was 'Fuels For The Future', and featured a total of eleven talks, touching on topics such as national and international policy, past and present experience of potential fuels, as well as the future of carbon, low carbon, and hydrogen fuels. It drew an audience of more than thirty delegates from a wide background, professionally, as well as geographically. The meeting was opened by the Vice-Chancellor of Cardiff University, Dr David Grant.

The first speaker was Lars Waldheim from the Swedish combustion and gasification equipment company, TPS. After an initial introduction to the activities of his company, he went on to give an incisive overview of the policy framework which has impacted the development of most industries over the last few decades, from historical international legislation, to forthcoming small combustion plant legislation. The collation of all the information in one place was useful, and provided a context for many of the discussions throughout the day.

Following on from Lars' presentation, Iftikhar Khan of RWE npower gave a talk which highlighted the impact of one aspect of the UK policy, the Renewables Obligation Order. This has resulted in most large coal-fired power stations taking up biomass as a small proportion of their fuel feedstock, and Iftikhar gave the audience an insight into such operations at their Tilbury, Didcot, and Aberthaw power stations. He went on to discuss the outlook for biomass within large generation, specifically the relative costs of dedicated biomass power stations (including IGCC and fluidized bed configurations), and energy crops (crops grown primarily for use as a fuel).

As an interesting contrast, the next talk was provided by Artem Khalatov of the Ukrainian Academy of Sciences, and outlined the energy challenges which face the Ukraine in the coming years. Currently, the country relies heavily on fossil fuel, much of it imported from Russia; demand significantly outstrips domestic supply. In addition, the vast majority of their nuclear power generation capacity is destined to be decommissioned over the next decade and beyond. The potential sources of energy to fill the gaps that will appear are seen to be nuclear, and renewables; there is a possibility that as much as 28% of the nation's energy demands could be met from renewables, with significant

contributions from wind and biomass. However, it was recognized that without government support, renewable energy may well never see the light of day in the Ukraine.

The first talk of the day to discuss hydrogen was given by Ray Allen of Sheffield University. His topic was that of multi-stage thermo-chemical cycles as a means of improving the efficiency of hydrogen production processes, as well as reducing lifecycle CO₂ impact and cost. The current centres of research in the subject are the US, Japan, and Europe. The work at Sheffield has involved LCA (life cycle analysis) of various routes to hydrogen. It proposes the most efficient process, in terms of 'well-to-wheel' carbon emissions, to be the use of nuclear power to generate heat for the steam methane reforming. The use of the same heat in thermo-chemical cycles is a close second.

In the next talk, enticingly entitled 'Towards A Flame-Free Future?', Kevin Kendall of Birmingham University preached the virtues of fuel cells in comparison to combustion. Fuels cells can use fuels such as methane, natural gas, propane and even petrol and diesel. One of the problems is that with the longer chain hydrocarbons, the fuel cell has a tendency to get coked up. Fuel cells can operate at temperatures of up to 700 or 800°C, which allows them to generate reduced levels of NO_x. However, due to the materials used, constraints must be placed on the flexibility of these units; one example takes six hours to reach full operating temperature. However, this same unit is capable of 55% thermal efficiency, and with an integrated gas turbine, could theoretically achieve in excess of 70%.

In a critical analysis of the potential of hydrogen and biomass fuels, Nick Syred of Cardiff University discussed some of the lessons which could be learned from the current biomass market. Similar to the work carried out at Sheffield, Cardiff have performed LCA of a number of alternative transport fuels. The results show that hydrogen has a greater 'well-to-wheel' energy cost than conventional fuels, unless it is produced using renewable energy.

Nick also discussed the reasons for the success of bioenergy in countries such as Sweden, Finland and Austria. He highlighted three main reasons: geography (low population, large amounts of biomass), taxes/government incentive, and steady heat demand profile (more conducive to the installation of combined heat and power plant). He raised the point that, because not all these factors are present in the UK bioenergy industry, existing UK schemes are heavily dependant on government support.

The transport industry has a substantial contribution to fossil fuel depletion, and greenhouse gas emissions. Diane Lance, of Ricardo, gave an interesting overview of the current automotive fuels market, and its likely development in the short to mid-term. The key issues affecting the development of automotive fuels are sustainability (economic, environmental and social factors), global warming, and urban emissions. One of the methods of reducing the net carbon emissions of the automotive industry is the use of biofuels, which are considered carbon neutral, due to the closed carbon cycle of the source crop and the end use. Diane made the important point that the internal combustion engine is predicted to play a major role until at least 2030; fuel cell vehicles will have a very low market penetration, primarily due to the lack of a hydrogen infrastructure, market inertia, and the high cost of the technology, whilst advances in the conventional IC engine will result in an increasing penetration of technologies such as lean-burn petrol engines and hybrid vehicles.

One of the problems associated with the use of biomass in large scale power generation is its high variability. This was identified in the talk given by Greg Sims, detailing the experimental work being carried out by QinetiQ on the characterisation of liquid and gaseous biomass fuels for use in gas turbines. There is a significant lack of data on the fundamental combustion characteristics of many biofuels. Biomass feedstocks, such as wastes and crops, can be used to produce a range of fuels, including ethanol, methanol, syngas, Fischer-Tropsch fuels, and pyrolysis oils. The properties of these fuels can affect how a gas turbine is designed, in terms of emissions performance, safety and durability, stability and turndown, and other combustion behaviour.

'An Italian Perspective of Future Fuels For Power Generation' was presented by Mario Graziadio of the Italian power research institute, ENEL. Italy's current power generation portfolio is predominantly fossil fuels, with 18% from hydroelectric schemes. Italian generators are looking to increase their use of coal and orimulsion up to 50%, with a corresponding reduction in their dependency on gas and oil. They are hoping to achieve this through repowering many of their oil fired plant for coal firing. There is also interest in the co-firing of RDF and biomass at various coal-fired. Orimulsion and petcoke have also been co-fired in a number of coal-fired boilers. Other activities include the construction of an externally fired gas turbine, and the establishment of the Venice Hydrogen Park.

Whilst coal may not be seen as a 'future fuel', Brian Ricketts of UK Coal presented a case for its place in the fuel mix of the future, through utilization of advanced clean coal technologies. Currently, coal meets 17% of the UK primary energy demand, and 35% of the UK electricity demand. The UK Government predict coal use is to halve to 23 million tones per year by 2020. However, world

coal consumption is forecast to increase by 50% in a similar timeframe. Brian gave some figures as to the measures which would have to be taken to reduce CO₂ emissions to the point at which atmospheric CO₂ levels would stabilize. All involved drastic measures, with only CO₂ capture and storage from large power generation plant appearing to offer a realistic opportunity.

The last talk of the day was by Jianxin Chen of Alstom Power, and it introduced the GAS-ZEP (Zero Emission Power) concept. The concept is basically combustion without nitrogen in gas turbines; oxygen and gas are supplied to the turbine, with flue gas being recirculated to adjust temperature and flow. The aim of this process is to produce an exhaust stream with a high CO₂ concentration, ready for capture and storage. Alstom claim a cycle efficiency of 47%, including the penalty for oxygen production and CO₂ compression.

In summary, the meeting successfully provided an opportunity to get a taste of the technology that may be meeting global energy needs in the future. The diversity of subjects, attendees, and discussions made for a stimulating day, and a successful event.

Ben Goh
E.ON UK

4. NEWS FOR MEMBERS

Web site

Thanks to the initiative and hard work of Dr. Phil Bowen and his colleagues, we have an excellent new Web site: <http://groups.iop.org/CB/>

Travel Grants

The Institute of Physics Combustion Physics Group (IOP CPG) will probably be offering Travel Grants for major combustion conferences. For details, please see our Web site for updates.

Membership

We now have 168 members spanning a range of professional activities, industries, and University Departments.

Prizes

Prof. Alan Jones is examining together with IoP the possibility of offering annual prizes for the best PhD thesis in the field of combustion, the best theoretical work, and the best industry-relevant work. More details will be announced in the next few months.

Jobs

For those seeking jobs in a combustion-related field, in industry or academia, the following Web sites can be of assistance:

<http://physicswed.org/jobs/jobalert/>

<http://jobs.ac.uk/>

<http://www.combustioninstitute.org/>

AGM

Our Annual General Meeting will take place together with the Young Researchers event in Loughborough on 21 September 2005. Special announcements will be posted to the members.

5. NEWS ITEMS

“Give it some gas”, *New Scientist*, 14 June 2004:

A fantastic view of small-scale combustion (really small-scale!), that can possibly replace batteries and fuel cells for applications such as mobile phones. The realm of micro-combustion covers miniature methanol reformers, rotary engines, gas turbines, and a “swiss-roll” combustor. <http://archive.newscientist.com>

“Bio-fuels”:

Usage of bio-fuels (e.g. diesel-like fuels derived from specially-grown plants such as rape seed) is highlighted in the 2005 Budget as a means to achieve the UK’s Kyoto Protocol obligations. See also the reports by Peter Stephenson and Ben Goh in this Newsletter on the “Fuels for the Future” meeting, where many comments on bio-fuels and biomass in general are also made.

“Coal”:

A search on the BBC’s website (<http://news.bbc.co.uk>) with the keyword “coal” reveals a host of news items on pit closures, warnings about inadequate supplies, and China emerging as the biggest coal consumer. At the same time, the EPSRC Web site (<http://www.epsrc.ac.uk>) reveals a total current funding of about 19M through 74 grants on “combustion”, of which only three (3) contain the word “coal” in their title, with another four looking as if they may be relevant to coal combustion.

6. OBITUARIES

Many important people who have contributed immensely to combustion science unfortunately passed away recently. Below, we give summaries from obituaries published in *Combustion and Flame*.

Prof. A.G. Gaydon (1911-2004)

Professor Alfred Gordon Gaydon was a distinguished spectroscopist studying flames and shock waves. He has written a number of textbooks in this field, still used extensively today around the world. He graduated from Imperial College, London, in 1932, and then worked in the Shirley Institute of the British Cotton Industry Research Association. He returned to Imperial for a PhD and he remained there until his retirement. Prof. Gaydon’s research in the spectroscopy of flames is very well known to the combustion community – “whenever students wonder about the colour of flames, they will be referred to his publications” (F. Weinberg, *Comb. Flame* **138**, p.2).

Prof. J. P. Longwell (1918-2004)

Professor Jack Longwell was a chemical engineer who made very significant contributions to combustion science. He served the Combustion Institute as President between 1968 and 1970 and received the prestigious Sir Alfred Egerton Medal from the same organization in 1974. He studied at Berkeley and MIT and then worked at Exxon for 32 years. He joined the faculty at MIT in 1976. Professor Longwell developed the well-stirred reactor, the “Longwell bomb”, a textbook combustor that was originally used to understand flame loss in early jet aircraft and was then used to amass chemical kinetic information for a range of fuels, including alternative fuels that formed one of Prof. Longwell’s research interests. Other topics included coal and biomass combustion and emissions.

Prof. G. M. Faeth (1936-2005)

Professor Jerry Faeth was a well-known man in combustion, having made contributions to spray combustion, soot formation, droplet motion, and heat transfer. He was a professor at the University of Michigan, after spending some time at Penn State University. He served as editor of *Combustion and Flame*, *AIAA Journal*, and the *ASME Journal of Heat Transfer* and received a number of medals and awards for his research. He was one of the pioneers of micro-gravity droplet combustion and had contributed to NASA’s spacecraft safety studies.

7. CASH FOR ARTICLES

Articles for the Newsletter, on any combustion-related topic, thoughts, activities or viewpoints, are always most welcome! In the case of full-time students registered at a UK university and Young Researchers from industry, the Combustion Physics Group Committee will award £50 for items accepted for publication. Articles should normally occupy between one and two pages in the Newsletter. Contact any of the Committee members to discuss this topic.

8. USEFUL WEBSITES

<http://www.iop.org>
<http://www.epsrc.ac.uk>
<http://monet.me.ic.ac.uk>
<http://www.cerfacs.fr/cfd>
<http://www.ge.com/aircraftengines/ge90>
http://www.gm.com/about/info/overview/RD_Center
<http://www.honda.co.jp/eng>
<http://www.lmm.jussieu.fr/Animations.html>
<http://www.forbrf.lth.se/spark>
<http://web1.mitsubishi-motors.co.jp/inter/technology/GDI>
<http://ivory.lm.com/%7Ecombust/index.html>
<http://cdr.stanford.edu/html/ME/faculty/mitchell.html>
<http://www.afrinc.com>
<http://www.itm.rwth-aachen.de/ercoftac/Welcome.html>
<http://www.ca.sandia.gov>
<http://www.et.byu.edu/cheme>
<http://www-mpl.sri.com:80/orgs/mpl.html>
<http://www.fe.doe.gov>
<http://www.altavista.digital.com>
<http://www.fetc.doe.gov>
<http://www.engin.brown.edu/faculty/suuberg>
http://vayu.che.caltech.edu/~ees/Faculty_overview.html
<http://www.lead.ruhr-uni-bochum.de>
<http://www.combustioninstitute.org>
<http://www.gk2k.ch.cam.ac.uk>
<http://www.opticspages.com/>
<http://www.zarm.uni-bremen.de/>