



The Royal Academy
of Engineering

Distinguished Visiting Fellowship Scheme Case Study

Turbulent Stratified Combustion



Host:
University of Cambridge
Professor Simone Hochgreb
Professor of Experimental Combustion



Distinguished Visitor:
Dr Robert S. Barlow
Distinguished Member of Technical Staff
Sandia National Laboratories,
USA



University of Cambridge and Sandia National Laboratories have complementary research interests in turbulent stratified combustion.

Dr Barlow is an international expert in the development and application of laser diagnostics for turbulent combustion. He is a recipient of the Silver Medal of the Combustion Institute, and he has been an invited speaker at Gordon Conferences on Laser Diagnostics and a plenary lecturer at the International Combustion Symposium. He has served as an editor of the Proceedings on the Combustion Institute and a member of the editorial boards of Progress in Energy and Combustion Science and Combustion Theory and Modelling. Dr Barlow is also the main organizer of an ongoing series of international collaborative workshops on Measurement and Computation of Turbulent Nonpremixed Flames (TNF) with an extensively cited experimental database on non-premixed turbulent flames.

The Engineering Department at the University of Cambridge has a growing research group in the area of experimental, theoretical and numerical combustion. Professor Hochgreb joined the Engineering Department at Cambridge in 2002 as Rolls-Royce funded Chair of Experimental Combustion, bringing her expertise in combustion to the challenging field of lean combustion in gas turbines.

Why a visit?

The visit combined the expertise at both institutions to study stratified combustion via a simple burner, which was developed at Cambridge University and investigated using planar imaging techniques. The discussion of potential collaborative work was initiated during the 31st

International Symposium on Combustion in August 2006, and the Cambridge stratified burner was sent to Sandia for experiments the following summer. These were the first experiments on stratified combustion in Dr Barlow's laboratory and the first to use a new detection system for simultaneous line-imaged measurements of Raman scattering, Rayleigh scattering, and laser induced Carbon Monoxide (CO) fluorescence. The Cambridge and Sandia data are being combined to determine the effects of stratification on geometric and statistical properties of these flames.

Joint analysis of results from the application of these combined laser diagnostics to stratified flames could not have been accomplished effectively without an extended visit and the resulting direct exchange of ideas. The visit also allowed for the setup of a laser diagnostic system for line-imaging measurements of CO concentration by two-photon laser-induced fluorescence (LIF) and transfer of knowledge regarding this technique to Cambridge researchers.

Statement from the Host

'Dr Barlow brought extensive experience in laser diagnostics in combustion and his visit allowed closer ties to be established between the newly established Centre for Combustion Research at Cambridge and Sandia National Laboratories.

We are very honoured by his visit and hope for a productive relationship.'

Professor Keith Glover FEng FRS
Head of Department

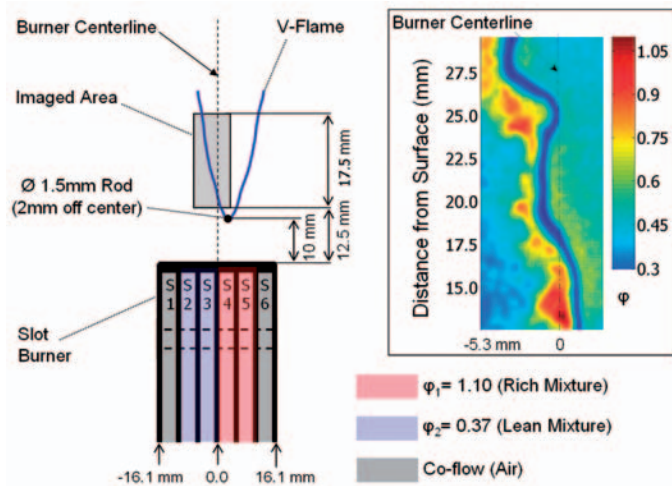


Diagram of the Cambridge stratified slot burner showing a rod-stabilized V-flame with one side intersecting the turbulent mixing layer between reactant streams of methane and air having two different equivalence ratios, ϕ_1 and ϕ_2 . The inset shows an example of planar imaging of acetone, as a cold fuel marker on the left side of the blue interface, and OH, as a marker of the edge of the flame and combustion products, on the right.

Visit Activities

The main activities during the visit included the collaboration on processing and interpreting recent experimental results from the stratified burner and writing joint papers on the stratified combustion experiments. Cambridge personnel were also able to directly implement and learn techniques for measurement of carbon monoxide in flames. Significant time was also spent developing ideas for further collaboration.

Statement from the Host

'The Combustion Research facility at Sandia National Laboratories hosts some of the best experimental and computational facilities in the world and produces some of the highest quality output in combustion. Transferring the knowledge obtained by their researchers and strengthening the collaborations with such institutions are crucial to producing high impact, effective research within the UK.

Dr Barlow's visit succeeded in the primary purpose of solidifying and expanding the collaboration between Sandia and the University of Cambridge, as well as on the specific objectives of producing immediate output and training in a new technique.

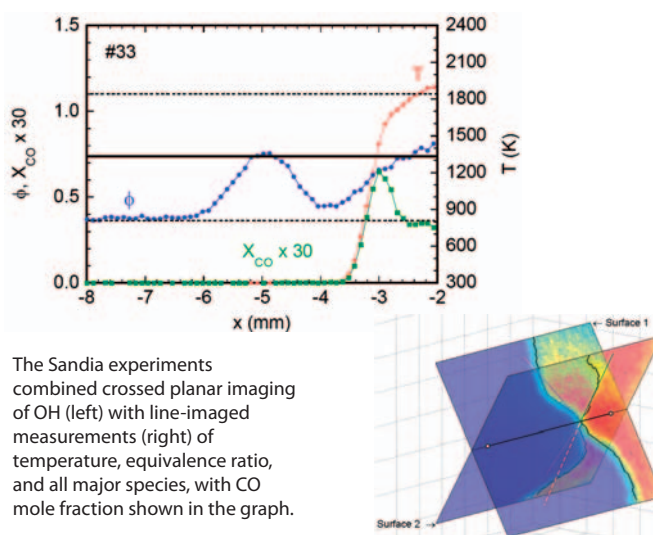
The visit energized the group for the whole period Dr Barlow was here. The students and researchers were able to learn first hand, in the laboratory, about a number of techniques, which proved invaluable in getting the system up and running. The interaction between Dr Barlow and the combustion modellers also provided a wealth of ideas for further analysis and new experiments. We would be very keen on bringing him back under a similar scheme.'

Professor Simone Hochgreb
University of Cambridge

Statement from the Distinguished Visitor:

'The RAE Visiting Fellowship Scheme has impressed me as a highly effective catalyst for international collaborative research. This was my first extended visit (beyond one week) to any university, and it created opportunities for generation of new research ideas and relationships that cannot be achieved in any other way. Having invested a significant portion of my own career in promoting collaborative research in the field of turbulent combustion, I applaud this RAE Program and would recommend it highly to colleagues.'

Dr Robert Barlow
Sandia National Laboratories, USA



The Sandia experiments combined crossed planar imaging of OH (left) with line-imaged measurements (right) of temperature, equivalence ratio, and all major species, with CO mole fraction shown in the graph.

Visit Outcomes

Two papers were submitted and have been accepted for publication. The optical setup for the CO-LIF was implemented and tested. Several opportunities for further analysis of the present Cambridge and Sandia data sets were identified. The visit also resulted in numerous discussions and interactions with students in Professor Hochgreb's research group, and some very fruitful discussions with researchers involved in modelling turbulent combustion. Dr Barlow benefited from the experience in Cambridge on combustion modelling and alternative image processing techniques for planar laser induced fluorescence (PLIF).

Future links and collaboration

The discussions during the visit provided ample opportunity to follow on with concrete next steps. Plans were made to enable the mining of the existing database on the imaging and line Raman measurements on the stratified burner. Plans were also made to develop and test at Cambridge a second prototype burner, which offers closer similarities to practical combustors, and to take the prototype to Sandia for line Raman diagnostics next summer. The visit resulted in a number of ideas for research proposals expanding the theme, to be further developed in the near future. Discussions with Cambridge researchers pointed to possibilities of extracting further information on premixed and stratified flames from the Sandia data. The visit also promoted the expansion of the TNF Workshop series to include stratified flames.

For further information please contact

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The scheme application form and guidance notes for applicants are available to download from The Academy's website:

<http://www.raeng.org.uk/research/researcher/dvfs/apply.htm>