Editorial

Following the success of our AGM and associated talks at Oxford last year, we are again holding this year's outside London. Unfortunately, your Editor couldn't attend the Oxford meeting as he was snowed-in: let's hope for more clement weather this year. It will take place on Wednesday December 15th 2010 in Room 9, Staff House, University of Manchester (Sackville Street Campus). This is less than 5 minutes' walk from Piccadilly station. On the basis that most people will be coming from well outside Manchester, we have booked lunch for 12.00 with registration probably starting at 12.30. Details, together with a map of the location, are given elsewhere in this newsletter. There is no charge for attending the meeting. I do urge you to come if you can. The AGM is normally quite short but does give members the chance to raise important points if they wish and to get a flavour of what the Group has done over the past 12 months and intends to do in the next. The provisional minutes of the 2009 AGM will be distributed at the meeting. However, the main attraction will be the lectures, or rather talks, that are the heart of our Christmas meetings. These are given by experts in their particular field, and I can vouch for the fact that they are as entertaining as far as is consistent with imparting useful information.

In the scientific arena, graphene research and carbon nanotubes continue to be hot news (see the notice about the most recent Nobel awards on page 2), and as the former originates in Manchester, it gives all the more reason to come to this meeting. Unfortunately the Nobel laureates will be in Sweden at the time of the meeting but we hope they will give us the benefit of their discoveries sometime in the future.

As you will see later in the newsletter, the SCI are sponsoring in conjunction with the BCG, a new award "Carbon in Industry". Details were widely circulated and the date for applications has now passed but we hope that the recipient of the award will give his or her lecture at the Christmas meeting-yet another reason to come.

We have a number of meetings that the Group is either helping to organise or is associated with and details of these are given in the newsletter. Prof. Sergei Mikhalovsky is organising for us a meeting at Brighton in September 2011 under the auspices of the EU FP7, the title of which is provisionally "Applications of carbon science in medicine". He has secured substantial EU funding for this meeting, which will have significant input from other European research workers. Sergei has also had an invitation to be a plenary lecturer at a symposium in Moscow next year to commemorate the life and work of M .M. Dubinin, a major figure in the field of adsorption on carbon surfaces. Given the considerable reputation of Dubinin's work, this invitation is quite an honour on which Sergei is to be congratulated. We have also received notices of other European meetings that will be interest to at least some BCG members: these are also included in this issue.

I'm grateful to Tony Wickham for providing an account of the IAEA data base and other information on nuclear graphite. May I remind all readers that I'm happy to publish anything that is relevant to the field of carbon science and technology, especially as you will reach a targeted audience.

Norman Parkyns *norman.parkyns@tesco.net*

Nobel prize for Physics 2010

I imagine that most of you must know by now that this year's Nobel prize went to Andre Geim and Konstantin Novoselov of the University of Manchester, for their work on graphene. In congratulating them, it gives us special pleasure that the award should have been for their ground-breaking work in yet another new field of carbon research. Unfortunately, they are (understandably) too busy receiving their award and giving associated lectures to attend the BCG's Christmas meeting but I hope that we shall be able to have a fuller version of their work in a future issue of this newsletter. Kostya Novoselov did give us a report in our 2006 meeting about the work in progress at Manchester on graphene at that time and there is no doubt that work in this area is one that has attracted a lot of attention not only in the relevant research areas but also in the public media.

The British Carbon Group

Notice of 2010 Annual General Meeting

Notice is hereby given that the 2010 Annual General Meeting of the British Carbon Group will be held at the start of the Christmas half day meeting on Wednesday 15th, December 2010 at 12.45 pm., at Room 9, Staff House, University of Manchester, M1 3BB

The business of the Meeting is as follows: -

1. Apologies for Absence
2. Minutes of the previous AGM (Held at The University of Oxford, 18th December 2009).
3. Matters Arising
4. Chairman's Report
5. Treasurer's Report
6. To Receive Notice of the Representatives of the Sponsoring Bodies
7. Election of Officers and committee members.
8. Any Other Business

At the 2009 AGM the Treasurer and Hon. Secretary must retire and offer themselves for re-election. Nominations for these positions are invited. In addition the positions of three ordinary Committee members fall vacant this year and nominations for these three positions are also invited.

Nominations duly proposed and seconded and with the consent of the nominee, should be received by the Honorary Secretary before 8th December, 2010 at the following address:

Dr. P. C. Minshall
Oldbury Technical Centre,
Oldbury Naite,
South Gloucestershire
BS35 1RQ

e-mail: peter.c.minshall@magnoxnorthsites.com

15th December 2010

12:00pm

Venue
Staff House,
University of Manchester

Registration
Email: g.b.neighbour@hull.ac.uk

BRITISH CARBON GROUP CHRISTMAS MEETING & ANNUAL GENERAL MEETING

The British Carbon Group

A half day meeting will be held on Wednesday 15th December at the University of Manchester devoted to latest developments, future prospects and cross-fertilization between three principal domains of carbon research: diamond, graphite and nanocarbons.

12.00 Buffet Lunch

12.45 AGM for BCG members

13.30 Welcome - Dr Gareth Neighbour
Chairman of BCG & University of Hull

13.35 The SCI Carbon in Industry Award & Lecture

14.25 Prof Mark Thomas (Newcastle University)
Adsorption of Hydrogen on Porous Materials

15.05 Tea & Coffee

15.35 Dr Paul Mummery (University of Manchester)
3D Imaging of Natural and Synthetic Composites

16.15 Dr Anthony Wickham
A Graphite 'Pile' in Your Backyard: The Future, or Fantasy?

16.55 Meeting Close

The British Carbon Group (registered charity 207890) is affiliated to The Royal Society of Chemistry, The Institute of Physics and The Society of Chemical Industry.

SCI RSC Advancing the Chemical Sciences IOP Institute of Physics

There is no registration fee for the above meeting

The University of Manchester
Sackville Street Campus

Route information

TO MANCHESTER FROM THE NORTH VIA M6 M61:
Follow STRETFORD signs into M60. Leave at Exit 12 and join M602 SALFORD. At end of Motorway, follow A57 MANCHESTER sign (Regent Road) for approx. 1 mile. Proceed under railway bridge, continuing into A57M (Mancunian Way). Continue on A57M, take 2nd exit. Immediately fork right on slip road into Sackville St following University sign Turn left at the Retro Bar into Charles St for the NCP CAR PARK.

YORKSHIRE VIA M62/M60:
Leave at Exit 17 signed Mcr CITY CENTRE, and follow A56 towards Manchester for 4 miles (Bury New Road, becoming Gt. Ducie St.) Enter city under railway bridges and keep straight ahead, still on A56, into Deansgate. In 1/2 mile, after passing KENDALS store, left at traffic lights (signed UNIVERSITIES) into John Dalton St. and straight ahead at next lights into Princess St. In 1/2 mile, pass under railway bridge and immediately turn left at lights into Charles St. NCP CAR PARK is on left.

DERBYSHIRE VIA A6:
Follow A6 signs towards Manchester City Centre until reaching the flyover junction with A57M. Continue on A6 and in 200 yards pass under railway bridge and turn left at traffic lights into Fairfield St. Pass Sackville St Building on left in 200 yards and then turn left at next lights into Sackville St. Pass under railway bridge and turn right into Charles St. for NCP CAR PARK.

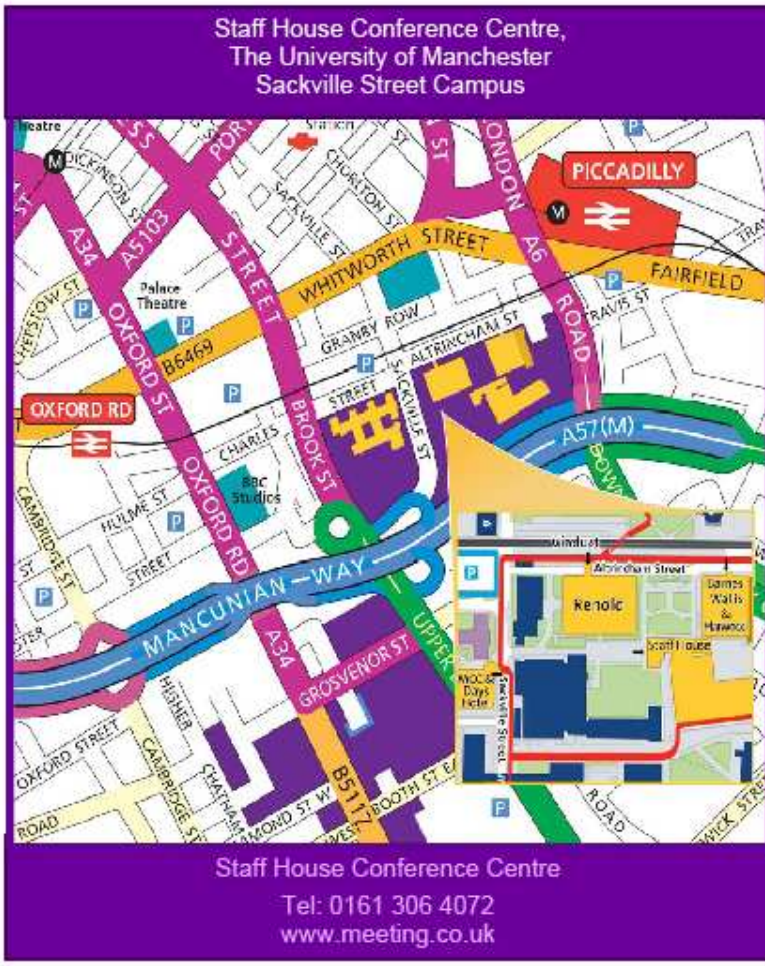
THE POTTERIES VIA A34:
Follow signs for Manchester through Congleton. 3/4 mile through Alderley Edge, take 2nd exit at roundabout still following A34. In 7 miles, pass over M60 and continue for a further 3 miles. At roundabout, take 2nd exit, following LONGSIGHT signs. (Ignore the A34 for the City Centre, which takes the 1st exit and passes under the railway) In 1 mile, merge with A6 and follow this road towards the City Centre as for DERBYSHIRE.

THE SOUTH & MIDLANDS VIA M6:
Leave at Exit 19 and follow A556 MANCHESTER for 4 miles. Join M56 MANCHESTER at roundabout and follow to end as for NORTH WALES & CHESTER.

NORTH WALES & CHESTER VIA M56:
Follow MANCHESTER signs, past Manchester Airport to end of M56 Motorway and keep straight ahead into A5103 MANCHESTER for 4 miles. On reaching roundabout beneath overhead road take 3rd exit following A57M SHEFFIELD signs to next roundabout; then 2nd exit up ramp to join A57M. Keep to near side lane for 200 yards and leave at next exit signed UNIVERSITY. Immediately fork right on slip road, following UNIVERSITY sign. Turn left at the Retro Bar into Charles St. for the NCP CAR PARK.

MERSEYSIDE VIA M62:
Leave at Exit 12 and join M602 MANCHESTER. At end of this MOTORWAY follow A57 MANCHESTER as for THE NORTH.

RAIL
PICCADILLY STATION:
Head for the escalators to the left of the concourse, following the signs for 'Taxis'/Fairfield Street. Immediately outside the station main entrance, turn right and cross London Road to the Bulls Head pub. Keeping the Bulls Head on your right walk down London Road & turn right again immediately after the railway viaduct, onto Altrincham Street. Continue straight ahead, and to your left you will see the Barnes Wallis Building/Harwood; continue ahead for a short distance and you will see a set of stone steps on your left leading down to a landscaped lawn. The Staff House Conference Centre is on the other side of this lawn and can be clearly seen from here, with entrances at either end of the building.
OXFORD ROAD STATION:
At the bottom of the station approach, cross over Oxford St. into Whitworth St (to the right of the Palace Theatre). Turn right before the University's Sackville Street Building and continue along Sackville St.. Proceed under the railway viaduct, turn left immediately before the security lodge and continue along the pedestrian walkway. Continue past the Renold Building on your right and you will come to a set of stone steps leading down to a landscaped lawn. The Staff House Conference Centre is on the other side of this lawn and can be clearly seen from here, with entrances at either end of the building.
VICTORIA STATION:
Take the MetroLink Tram to Piccadilly Rail Station. Exit to the street at platform level following signs for 'taxis' and continue directions as for PICCADILLY STATION.



Annou ncements of Conferences and Courses

NanoteC10

This conference, organised and supported by the BCG, will take place at Corpus Christi College, Oxford University, September 1-4th 2010. Full details are available on our website *www.britishcarbon.org*

3rd International Carbon Composites Conference

After the success of the 2007 and 2009 editions, the organisers are pleased to announce the organization of the:3rd IC3 - International Carbon Conference, to be held in Arcachon, France, October 25-27, 2011. Contact the secretariat:*jfb@avantage-aquitaine.com* if you would like to make a delegate pre-reservation, submit an abstract, or book an exhibition booth in advance.

Visit the web site: *www.avantage-aquitaine.com*

European Course on Carbon materials

We have received a general invitation to the intensive course “European Course on Carbon Materials” presented by the German Carbon Group (AKK) in cooperation with DECHEMA e.V.

which will be held from 18 – 19 November 2010 in Frankfurt am Main/Germany. You can find further information on the website: http://kwi.dechema.de/en/cm.html..Contact Dr. Gruß, (see below), if you have any questions.

Nicola Gruß
DECHEMA e.V.
Weiterbildung
Theodor-Heuss-Allee 25
60486 Frankfurt am Main
Germany

Symposium to commemorate M. M. Dubinin

The Scientific Council on Physical Chemistry, Russian Academy of Sciences, A.N. Frumkin Institute of Physical Chemistry and Electrochemistry, RAS, the Russian Foundation of Fundamental Research are planning an international conference devoted to 110 anniversary of Michael M. Dubinin "Modern Problems of Adsorption" October 24-28, 2011 in Moscow.

2011 marks 110 years since the birth of the famous chemist, Academician of the Russian Academy of Sciences, Professor Mikhail Mikhailovich Dubinin. Dubinin is well-known in the history of science as the author of “Theory of volume filling of micropores”, co-author of the well-known Dubinin-Radushkevich equation and classification of adsorbents, reflecting the nature of adsorption processes.

M.M. Dubinin Scientific School continued to prosper in the Institute of A.N. Frumkin Physical chemistry and electrochemistry, RAS. The Institute has a Laboratory of kinetics and dynamics of adsorption (Head, Doctor of Science in Chemistry, Albert Voloshchuk), Laboratory of equilibrium adsorption (Head, Doctor of Science in Physics and Mathematics, Anatoly Fomkin), Laboratory of synthesis and study of the sorbents (Head, Ph.D. Galina Petukhova).

The SCI ‘Carbon in Industry’ Award & Lecture 2010

This prestigious award has recently been established by the Society of Chemical Industry and the Award will be given for the first time in 2010. The award seeks to recognize the contribution made by leading industrial scientists and engineers to carbon science and technology such as any significant contribution to developmental work, pre-commercialization, and / or promoting interaction with other sectors of society, *e.g.* public understanding of science.

Nominations are now requested without the knowledge of the candidate and with a supporting 250 - 500 word citation. The BCG Executive Committee will then determine the awardee on the basis of independent scoring against the criteria of track record, citation submitted and industrial impact. Self-nomination is not permitted. The successful candidate is likely to have more than 10 years industrial experience and have made a significant contribution / impact within an industrial sector either by the creation of knowledge (*e.g.* evidenced by patents, development of industrial plant, *etc*.) or having shown excellence and a high degree of industrial leadership within their organization by making a significant impact upon the UK's social, environmental and economic well-being. The awardee will hold the respect of their colleagues and their contribution well-known in their particular field.

The ‘Carbon in Industry’ Award will consist of £500 and a certificate. We will expect the recipient, as a condition of the award, to receive their award at one of our meetings, usually the Christmas meeting, and to

present an award lecture outlining their contribution to carbon in industry. Reasonable travel expenses will be paid by the BCG. Thus, the inaugural lecture is likely to occur in December 2010.

The closing date for nominations will strictly be 4pm BST **1st September 2010**. No submissions after this date will be accepted.

Applications may be submitted electronically to the Chairman of The British Carbon Group, Dr Gareth Neighbour, at g.b.neighbour@hull.ac.uk or, exceptionally, mailed to him at the following address:

Dr Gareth Neighbour,
Chairman, The British Carbon Group,
Department of Engineering,
University of Hull,
Hull, HU6 7RX, UK

Reports on past Conferences

BCG meeting at BAT, Southampton

In April 2010, we had our spring meeting "Carbon and Industrial Applications" hosted at British American Tobacco in Southampton. The meeting attracted 49 attendees from both academia and industry. It was pleasing to note that delegates were attracted from 8 different countries overseas with a strong interest in industrial applications such as activated carbon and the performance of carbon filters. As such, the meeting provided an excellent opportunity for cross fertilization of ideas and knowledge from the many branches of carbon science. The BCG is very grateful to BAT in Southampton for their hospitality and facilitating this exciting meeting which allowed members to attend without charge. Special thanks go to the Organizing Chairman, Dr Peter Branton, for his excellent skills in putting the programme of speakers together and providing his time. There were six carefully prepared presentations which provided the current state of the art with the latest industrial applications of carbons which included aspects of carbon adsorbents, activated carbons, carbon filtration, and applications of carbon in smoke, defence, nuclear and water industries.. The meeting concluded with an impressive tour of BAT's research laboratories and hearing some of their latest medical research and the development and performance measurement of novel carbon materials."

Gareth Neighbour

Photo of the attendees at the BAT meeting.

Carbon 2010

University of Clemson, Clemson, South Carolina, United States of America

11th to 16th July 2010

The Annual World Conference on Carbon, first initiated in 1953, is an annual event incorporating all areas of carbon science. Since the year 2000 Carbon has been alternately held in Europe, America and Asia. It provides an opportunity for individuals and groups from both academia and industry to discuss their work and enhance their knowledge of other Carbon related topics. The slogan for this year's conference, 'From Nano to Macro', sums up the huge range of research applications currently being undertaken in carbon science. Engineering, chemistry and biology are just a few examples of research areas that are benefitting from the extraordinary properties of carbon. It is therefore little surprise that Carbon 2010 included approximately 450 delegates from a range of countries that was reminiscent of the opening stages of the world cup!

The amount of information being presented that was directly applicable to my research area (modelling of mechanical properties and fractography of industrial graphites) was not particularly great. However, I did gain a greater insight into the methodological approaches and experimental techniques used on a range of carbon materials used in different applications of carbon science. In addition, these talks, mostly focusing on a physical scale much smaller than that I usually work, gave a greater understanding as the true complexities and capabilities of this remarkable element.

Being an engineer, I attended talks mainly focused on microstructures and mechanical properties in an attempt to understand as much as possible. I did however, make an effort to broaden my knowledge to other scientific disciplines and took a particular interest in biological applications. Admittedly, it was a struggle to follow some of the more complex concepts during these presentations. However, I was able to pick up a few points and identified some potential areas for further reading.

There was a great deal more to the conference than being constantly bombarded with science. The social agenda was very full and contained a wide variety of enjoyable activities. A personal favourite was a hog roast BBQ at an old cotton plantation with locally produced beer and a bluegrass grass band. Add to that fireflies and a thunderstorm and it made for a truly unforgettable 'Southern' evening (and perhaps, a very clichéd one!).

My presentation was the first Keynote on Tuesday morning. I was talking about 'A New Methodology for Modelling the Failure Characteristics of Nuclear Graphite'. The talk went very well and after a few nerves at the start I managed to deliver it in a confident and competent manner.

The conference was very successful in broadening my understanding of varied and novel uses for carbon. In addition, it gave me an opportunity to present my work to a large group of professionals on an international stage. I am certain that this conference will be remembered as a very enlightening and enjoyable week in South Carolina. I would like to thank the Institute of Physics and the British Carbon Group for their support in allowing me to attend this conference.

Gary Kipling

Brian Kelly award 2010

Photo shows the 2010 winner Jean-Philippe Tessonnier (right), Fritz-Haber-Institut der Max-Planck-Gesellschaft, Berlin, Germany, with Gareth Neighbour.

Applications for the 2011 award are now open: details on our website *www. britishcarbon.org*

Letters received

Gareth got the following letter (overleaf) from Irene Suarez recounting life Down Under. It's printed as received. Because it's in pdf format, I can't do much about the size of the print but if you are looking at an electronic version of this newsletter, you will be able to open it. It's the first letter I've had the opportunity to publish as Editor but what a good idea. Thank you, Irene and may you be the first of many.

Dear Poms ☺,

At this year's NanoteC, Gareth asked me to write about life and science down under. So, here it goes.

I write to you from Western Australia, the largest state of Australia. Since November I have been a post-doc at Curtin University in Perth (the most isolated city in Australia). Life here is ace. The sun, the beaches, the barbies, I'm loving it. The first thing to get your head around here is the fact that "within cooee" (nearby) is three times what you expect. A bus stop is nearby if it is within 15 minutes walk, a place is within driving range if it takes less than 3 hours, and Bali is considered a close holiday destination even though it's a 4 hour flight! With all these distortions in distances, I was relieved to learn that an Angstrom is still 10^{-10} m like everywhere else.

Curtin is quite a recently founded university (it was made a university in 1986 according to the latest departmental quiz). I've included a picture of the Chemistry Department. The building walls represent grain boundaries, which fits with the science carried out inside where a lot of researchers explore surface chemistry and crystal growth.

As for carbon, Australia is not very rich in graphite. It has some diamond deposits, but mostly it has heaps of coal. So, Australia doesn't have an Australian Carbon group but rather the Australian Coal Association which is more of an industrial body than a scientific one. A lot of the British research on carbon was motivated by the nuclear industry. Australia doesn't have any nuclear stations (the country is mostly empty, 2 people per km^2!) but they do hold 23% of the world's uranium deposits. There are some groups looking at amorphous carbon, especially in the RMIT in Melbourne. And obviously the group of Prof. Nigel Marks that I joined looks at carbon!

This letter would not be complete without an account of the wildlife in Oz. I got bitten by some mosquito/spider/who-knows-what and my hand swelled up like graphite under irradiation. Ozzie flies are particularly annoying; they are able to fly in circles in front of your face even when you are walking. But I will leave you with the thought of sweet (delicious) kangaroos and lazy koalas.

I wish you all a white Christmas (I will be on the beach)
Irene

ESTABLISHING THE IAEA INTERNATIONAL KNOWLEDGE BASE ON NUCLEAR GRAPHITE

A.J. WICKHAM, G.HAAG**, L. RALPH*** and M. GLADYSHEV*****

**Nuclear Technology Consultancy, Builth Wells, UK, confer@globalnet.co.uk*
***Nuclear Technology Consultancy, Linnich, Germany, gdhaag@t-online.de*
****KorteQ Ltd, London UK, lee.ralph@korteq.com*
*****International Atomic Energy Agency, Vienna, Austria, m.gladyshev@iaea.org*

ABSTRACT

The issue of the potential loss of knowledge and experience in respect of irradiated nuclear graphite properties and the suitability of new graphite materials for nuclear moderator and reflector applications has been addressed initially by the established of an international database on irradiated nuclear graphite properties. This has now been developed further with the establishment of a knowledge base, accessible through the IAEA website at two levels. Basic information is available for the information of the general public, whilst more technical details, along with the numerical database, are accessible to registered users who work within the participating Member States of the IAEA. The content of the knowledge base will be contributed from all participants and discussed to confirm its validity and suitability before being uploaded for general access. We consider this programme to be an extremely valuable tool for the future use of carbon and graphite materials within the nuclear industry.

Key words: nuclear, graphite, knowledge base

Introduction

The issue of the potential 'loss' of knowledge and experience in respect of irradiated nuclear graphite properties was first raised in 1995 at an IAEA Consultancy Meeting. Graphite was developed as a nuclear moderating material in the 1940's, and has been utilised in production reactors in USA, USSR, France and the United Kingdom. More importantly, it is the basis of the Magnox and AGR programmes in the UK, the UNGG reactors in France and the RBMK designs of the former Soviet Union, and is also intended for application in future high-temperature reactors (HTRs).

A mass of irradiation data exists, and seven Member States of the IAEA initially, along with a number of graphite manufacturers (as sponsors) and the United Kingdom nuclear regulator, combined to create a Database of irradiated nuclear graphite properties, with the objective of archiving this information in a searchable Database to ensure that future designers and operators had full access to the accumulated experience.
Much of this information is specific to particular grades of nuclear graphite under particular operating conditions, but the knowledge remains of considerable value in predicting the behaviour of new grades of graphite currently in development (such as SGL's NBG-18 grade developed for the presently delayed PBMR programme in South Africa): there are strong indications that HTR programmes will also go ahead under the GenIV initiatives. In addition, the collected information represents a valuable resource for the development of operational safety cases for the advanced gas-cooled reactors currently in operation in the UK, and for the planning of decommissioning activities for all graphite plant.

Recently, it was decided to develop the project into a fully comprehensive Knowledge Base, creating and/or archiving documents of historical record and current interest in this field of nuclear graphite. The software for this has been developed by knowledge-management specialists KorteQ Ltd utilising the Microsoft

SharePoint® format, and can be accessed through the IAEA website by those who have registered an interest with their participating Member State. In addition, there is an 'open' knowledge WiKi which anyone can study. The Database, along with a record of conference presentations in the series of International Nuclear Graphite Specialists Meetings, is accessible through the site.

Additional IAEA Member States have expressed interest to join the project, and participants are now in the process of 'populating' the Knowledge Base with relevant documents to create what will be a fully comprehensive international historical record of the development and behaviour of nuclear graphites, to assist the continued use of graphite moderators in the development of nuclear power.

The Nature of the Database

Graphite has been utilised as the moderator material in early air- or water-cooled production reactors in the UK, USA, France, China and the former Soviet Union. From these early operations, two major designs of reactor utilising graphite and a carbon-dioxide coolant were developed in the UK – Magnox and the AGR (advanced gas-cooled reactor). France developed the UNGG fleet, also utilising carbon dioxide coolant, which has similarities to the Magnox design especially with regard to the Magnox-clad natural uranium fuel. The former Soviet Union developed the RBMK design in which the graphite is maintained under a blanket gas consisting of nitrogen and helium. A number of designs of high-temperature reactor are being developed, all of which use graphite as reflector material and as a component of the fuel (both in the prismatic and pebble-bed designs): in the HTR the coolant is helium. Graphite may also be employed as first-wall material in future fusion plant.

Under all of the applications, the graphite is exposed to fast neutrons which caused damage to the basic graphitic crystalline structure, resulting in dimensional changes of components along with significant changes in mechanical and physical properties can be of great significance in determining the 'lifetime' of the graphite components and also having significance for the reactor-physics and thermal behaviour[1]. Dimensional changes may lead to the development of stresses and ultimately to component fractures, although the phenomenon of irradiation creep mitigates this to some extent. Changes in properties like the coefficient of thermal expansion and the thermal conductivity clearly also have important safety implications.

Graphite moderators and reflectors also interact strongly with the reactor coolant gas where this is of an oxidising nature (*i.e.* air or carbon dioxide). In this situation, graphite is physically removed from the open-porosity of the material, as carbon atoms are oxidised to carbon monoxide (in CO_2) or to a mixture of CO_2 and CO (in air) [2]. The graphite becomes more porous, and thus less dense and potentially weaker, although some initial benefit can result if the graphite also becomes less brittle. However, the rate of oxidation, which is controlled by the local ionising-radiation dose rate, the coolant pressure and temperature (through the gas density), the nature of the porosity distribution, and the exact coolant composition (into which oxidation may be added, such as methane in the UK AGRs), impacts upon the changes in the mechanical and physical properties and can become the major controlling parameter over the eventual safe operating lifetime of the structure.

Nuclear graphites have also been manufactured historically in different ways which impact upon the relative importance of these 'graphite-damage' issues [*see, for example,* 3]. Most early graphite components were manufactured by extrusion, which leads to anisotropy in property changes: subsequent developments have seen the use of die pressing, isostatic pressing, and vibration moulding, and each of these creates a different alignment of graphite crystallites and crystallite size which impacts upon the subsequent irradiation behaviour. The nature of the materials used – filler coke and its treatment, pitch binder, etc. – also leads to graphites with different characteristics, particularly in grain size, which again result in differing behaviours.

The international specialists realised the importance of 'capturing' the totality of the known behaviour of the older types of graphite, even though most of them are no longer available, because the best available understanding of the historical behaviour record assists in evaluating the likely behaviour of presently-available and future graphite types. The number of high-flux irradiation facilities world-wide has significantly declined, and it is extremely difficult to get data on new materials quickly at a rate which assists the design of new plant. Indeed, much of the present experience of the performance of the graphite materials in the existing

reactor designs was obtained in parallel with their commercial operation, out of necessity. This will also be true of developing programmes such as the HTR-PM programme in China and the PBMR.

The creation of the Database over the period 1997-2009 was timely in the sense that data was genuinely likely to be lost forever. Two examples of this were the physical fading of data recorded only by dot-matrix printer output, and the recovery data never written up by certain laboratories and which was likely to be totally forgotten as the involved staff reached retirement age.

Database Structure

In the initial stages of the development of the numerical Database, a comprehensive relational Database was conceived utilising the basic structures of Microsoft Access®. As the size of the data collection increased, users found the search facilities more and more difficult to use successfully and consideration was therefore given to the development of a more comprehensive system using commercial tailored software. However, after detailed consultation with the users, who are essentially nuclear graphite specialists who are less familiar with more complex Database programming, it was decided to revert to a simple Microsoft Excel® spreadsheet format, from which data could be extracted easily by categories, and comparative graphs could be drawn using familiar methods, without difficulty to the users.

Although this approach has been criticised by some outside observers as being over-simplistic, it remains the clear choice of the users. The Database now contains over 33,000 lines of data extracted from the reported graphite-irradiation experience of the participating Member States. These data derive both from research studies in specially designed graphite-irradiation rigs inserted into materials testing reactors or ionising radiation sources, and from the operational reactors themselves. In the latter case, pre-characterised samples have been inserted into special carriers in positions with known irradiation dose rates for subsequent withdrawal and, in addition, methods have been developed over the years for the extraction of samples of graphite from the moderator components themselves using trepanning technologies. Many useful measurements can be made on such samples even though the material was not normally pre-characterised.

More than one hundred different parameters or properties are (where available) captured by the Database, and a snapshot is shown in Figure 1.

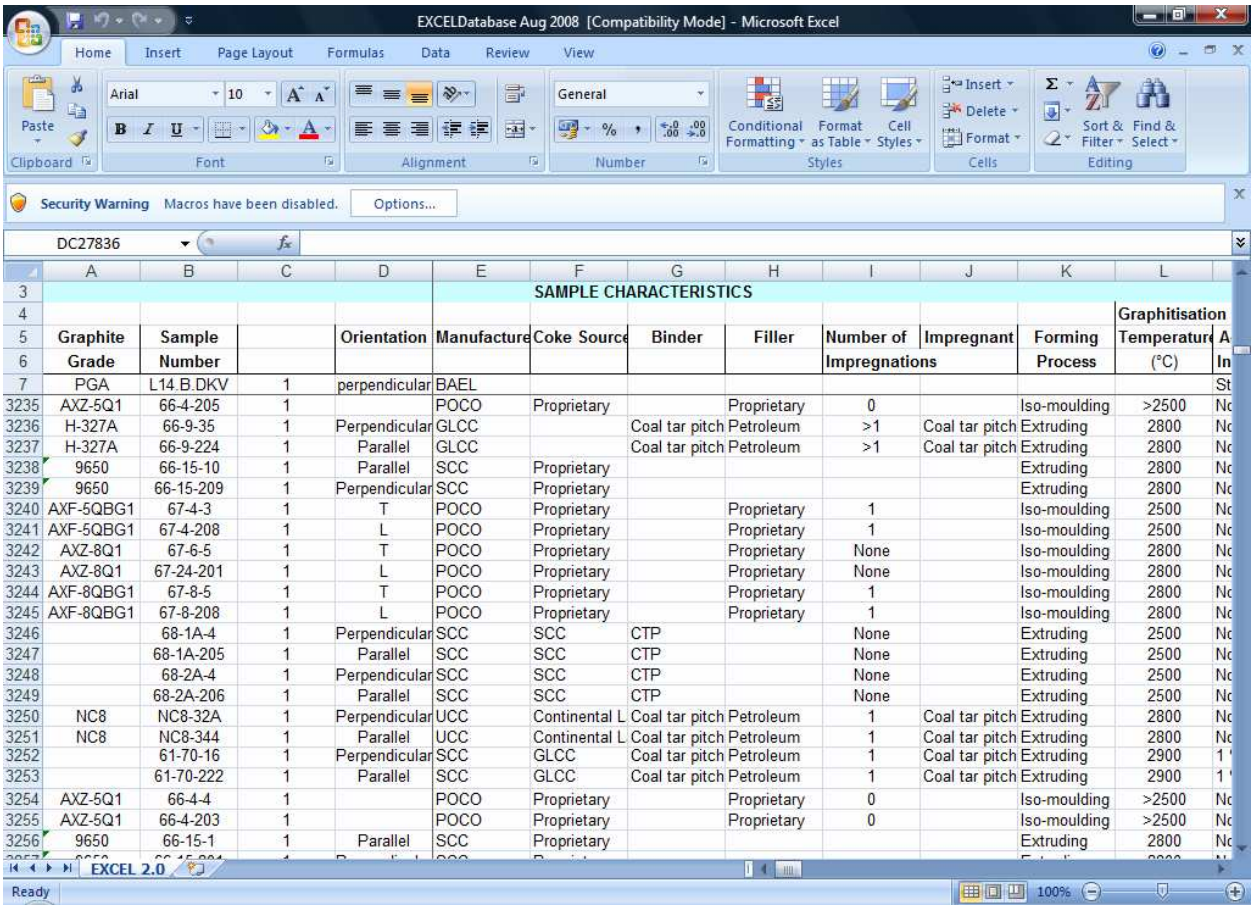


Fig. 1. *Snapshot of part of the nuclear-graphite properties Database*

In most cases the source document for the data is available, and this may be accessed directly through a hyperlink at the end of the data row to give the user additional information. A strict quality-control procedure is also in place, both to control the process of extracting data from original sources and inputting it into the Database, and also to provide a 'quality-assurance rating' (QA) for the original source material, as assessed by the project's technical steering committee which consists largely of graphite specialists. This latter is expressed in the form of a 'data string' which identifies the grading of essential features of the data, the nature of the irradiation and of the body undertaking the work and reporting it [4]: these 'data strings' are themselves hyperlinked to a standard QA format sheet which identifies these features precisely. The QA procedures are seen as an essential feature of this Database by designers and regulators when these data are employed in the safety case documents supporting continued operation of existing plant (principally in the UK) and for justifying the design parameters of new plant.

Up to 2009, the Database was distributed to authorised users in the participating IAEA Member States on CD-ROM (latterly DVD because of the file size), with password protection. Data within it remain the property of the organization or Member State providing it, and are generally available to anyone in appropriate organisations within the participating Member States. A formal 'Working Arrangement' sets out the conditions of use. Administration of the activity within the IAEA was through the Nuclear Data Section. However, with the establishment of the Knowledge Base into which the Database is now incorporated, access is via the Knowledge-Base home page (see below) which is managed within the IAEA Division of Nuclear Energy. The expansion of the Database will continue, under this new arrangement, as additional data are located or are made available: currently it is being specifically developed to assist an IAEA collaborative research programme on irradiation creep in graphite, which is identified by the specialists as a major weakness in nuclear-graphite understanding, and in the acquisition of irradiation data on 'matrix material' – the quasi-graphitic material utilised in HTR fuel compacts and pebbles. Further developments in composite materials are also planned in the future.

Knowledge-Base Features

The nuclear graphite Knowledge Base was established in March 2010. It had been recognised for some time that not only was there a risk of data being lost, but historical documents giving more general information about nuclear graphites were also in danger of being lost. Recent experience in other parts of the nuclear industry had led to the establishment of knowledge bases utilising Microsoft Sharepoint®, the key example being such a knowledge base developed for the graphite-core project team of British Energy (UK) by KorteQ Ltd, a UK knowledge and information management company who specialise in effective knowledge transfer to accelerate learning, reduce risk and improve performance. Another example of a stand-alone system supporting the understanding of the performance of reactor pressure-vessel steels was also examined by the project's technical steering committee.

After previewing both types of system, and after extensive discussions between the graphite specialists and the IT specialists, the present graphite knowledge base was established. The Sharepoint® system was selected, which has raised a small complication because the IAEA IT systems do not support this program. In consequence, an external hosting company must be used for the project, and this understandably attracts an annual fee.

It was decided from the start, in discussion with IAEA staff members, that it would be desirable to provide basic information on the nature of nuclear graphite for any individual perusing the IAEA websites, and there are therefore two levels of access, with the general access leading to a graphite knowledge 'WiKi' feature direct from the welcome page (Figure 2) at www.iaea.org/NuclearPower/Graphite/. This will commence with a very basic explanation of "What is graphite?" Over the coming months, members of the project will provide material to expand this area of the knowledge base, with the technical steering committee having the responsibility to ensure that information is current and to identify areas in which archive material is deficient. This will be done through providing the relevant topic areas of older documents with hyperlinked commentary giving access to the latest thinking.

Members with authorised access can log into an extended and more comprehensive version of the Knowledge Base (Figures 3,4). This is not intended to imply that the information is in some sense 'secret', but rather that it is presented in a form which is appropriate for those trained in nuclear engineering and with pre-existing knowledge of graphite behaviour. Again, this area of the knowledge base will be 'populated' over the coming months (or perhaps longer), but the technical steering committee has already identified the key topic areas as follows *(this list is greatly abbreviated)*:

Nuclear properties	Structure
Structural and dimensional changes	Electrical and thermal properties
Stored energy	Chemical properties (primarily oxidation issues)
Reactor operating experience	Radiation effects

In addition, archived presentations from the series of "International Nuclear Graphite Specialists Meetings", held annually since 2000, will shortly be added to the knowledge base.

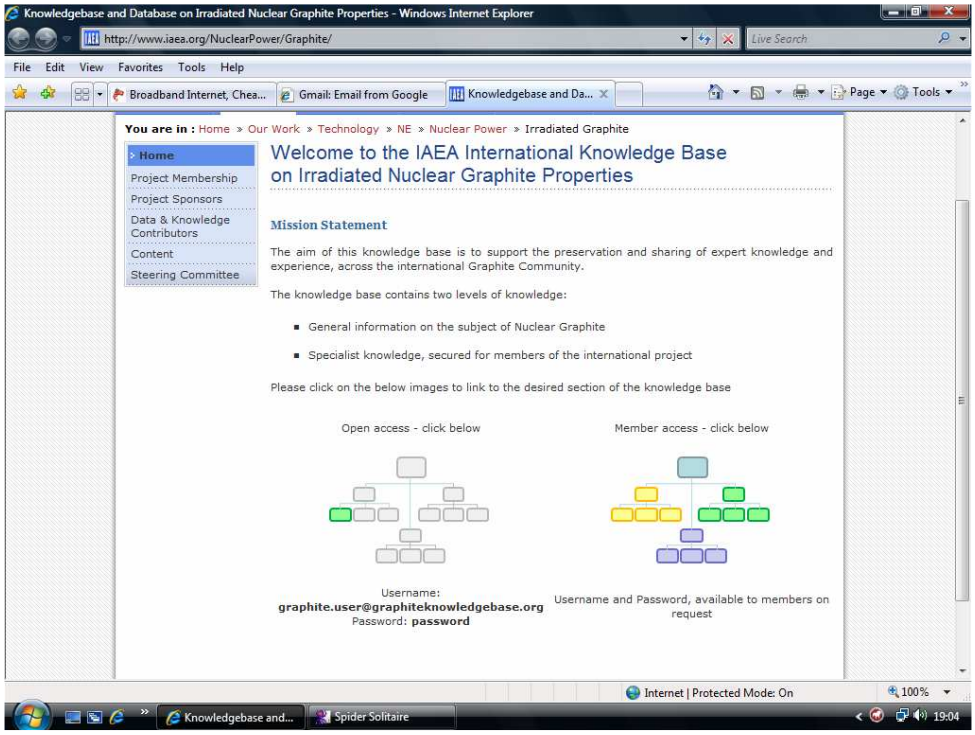


Fig.2. *Welcome page for the IAEA Graphite Knowledge Base*

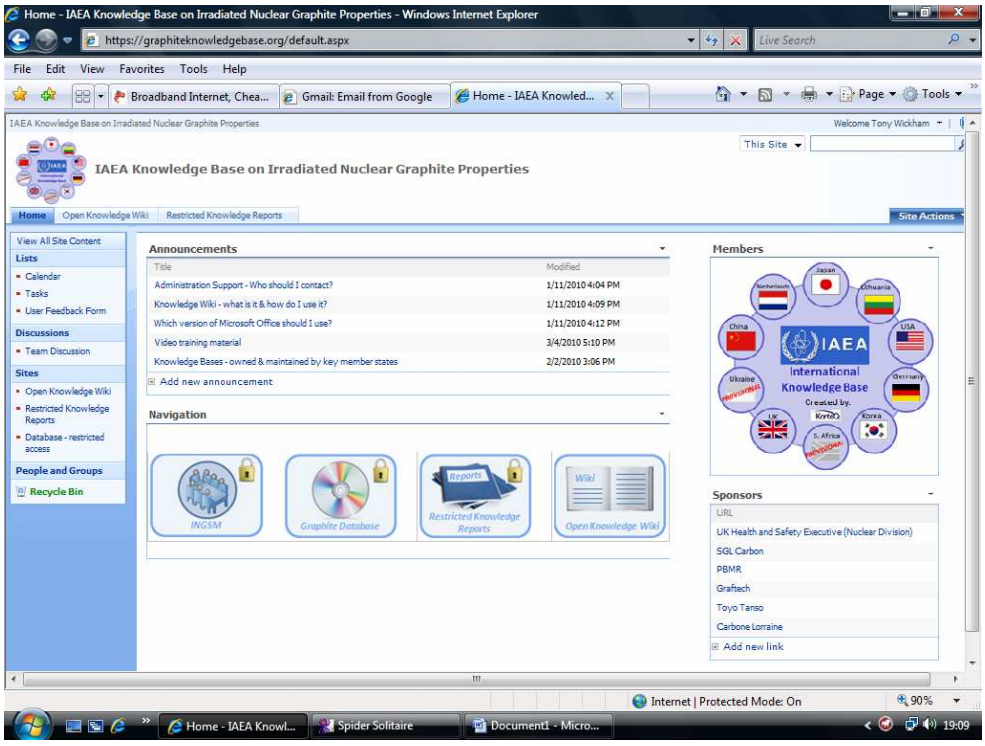


Fig.3 *Opening page for Knowledge-Base members*

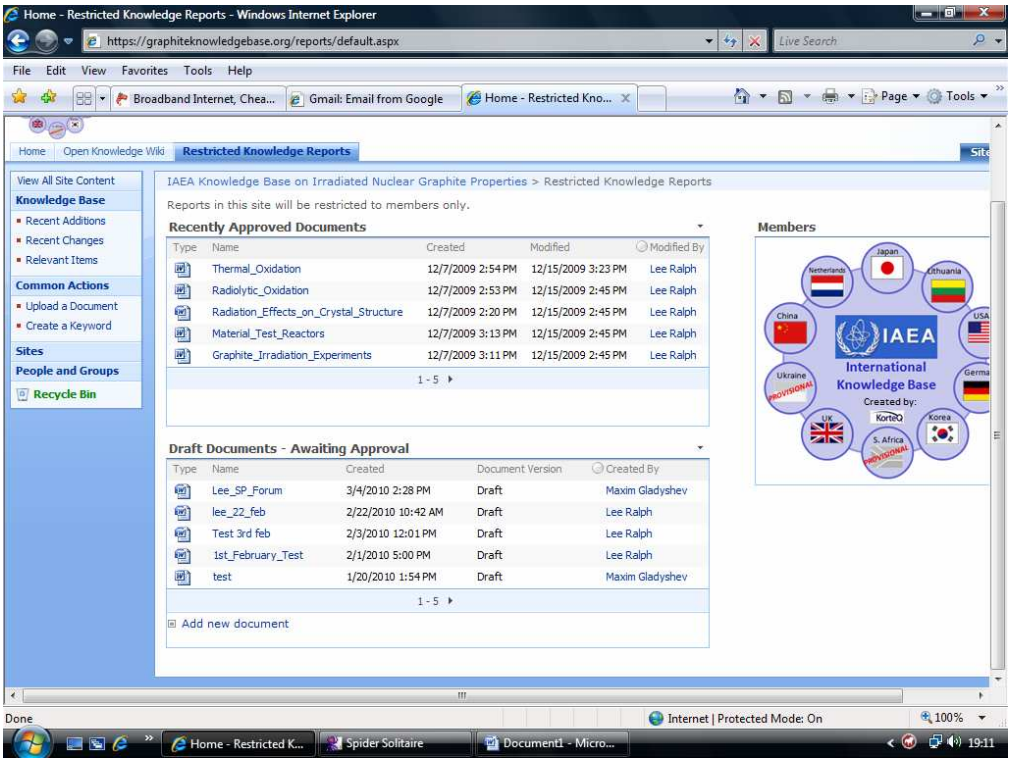


Fig.4. *Entry to the specialist knowledge-base content*

Roll-Out and Training

Due to the global nature of the project it was necessary to plan a remote system roll-out that could engage all of the present participating member states. To achieve an effective roll-out, KorteQ produced video based training material, including screen casts of the knowledge base and written supporting material where appropriate. The training material was delivered on DVD and is also accessible via the Knowledge Base from a hyperlink on the homepage.

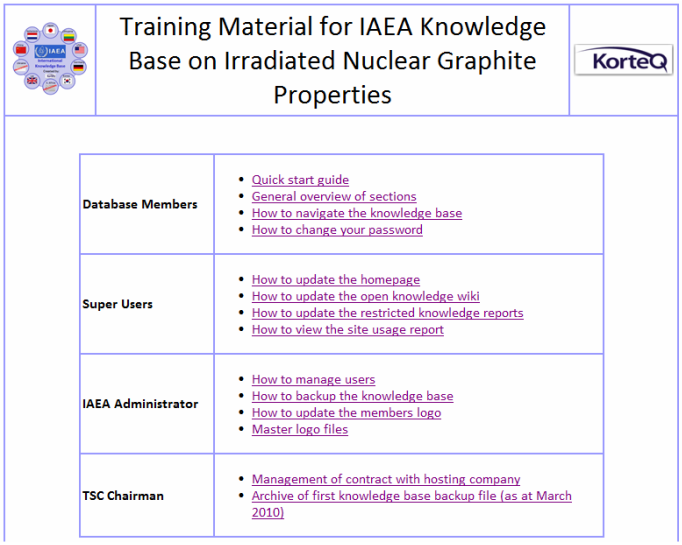


Fig.5. *Menu page of video training DVD*

It is important at this point to appreciate that the IAEA Knowledge Base on Nuclear Graphite Properties is a ‘work in progress’. Much will be added to this archive as time progresses. However, we do believe that it is an excellent example of knowledge management and transfer, and that it offers an appropriate template for similar systems in other areas of nuclear engineering.

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[3] UCAR Carbon Ltd *(now GrafTech Intl Inc.)*, The Industrial Graphite Handbook, 2001, The UCAR Carbon Company Inc. *(also available via www.graftech.com)*
[4] A.J. Wickham, G. Haag and D. Humbert, IAEA Report INDC (NDS)-500 Issue 2, 2008

Acknowledgements

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Ang and I

And who, I hear you ask, is Ang? It's a "what" actually: ANG stands for Adsorbed Natural Gas and it did play quite a major role in my professional life about 20 years ago. Many of you will know that I passed my time in gainful employment for the organisation that became finally British Gas plc, of blessed memory, and specifically at its London Research Station.. At that time, BG had a large research effort on gassy matters and a generous budget to pursue it. I was in charge of a group dealing with applications of physical chemistry mainly in gas kinetics, heterogeneous catalysis and gas/solid adsorption. Sundry other things would come and go in our direction but those were the three fairly firm topics we pursued.

I was sitting in my office one day, as one could in those days without being felt not to be pulling one's weight, when I got a phone call from Frank Derbyshire. I'd known Frank on and off for some time. He was a very able scientist and a very lively character as those who knew him will testify. His untimely death came as a great shock to us and left a big gap in our lives. He came straight to the point. "What is British Gas doing about ANG?" I heard to confess that (a) I didn't know what ANG was and (b) nothing, as far as I knew. Frank went on to explain that he had just been appointed Technical Director of Sutcliffe Speakman Carbons, a fairly well-known firm in the Gas Industry because it had supplied active carbon for many years during the days of coal carbonisation for removing benzene and its homologues, mainly for fuel use, from gas streams. In this capacity, he was in discussion with an American consortium about the possibility of involvement with a scheme for storing natural gas under pressure for automotive use. I knew that BG had nothing in its portfolio to do with using natural gas for transport, mainly because our redoubtable Chairman, Sir Denis Rooke, was convinced that if we got into this, the government would immediately slap a tax on the use of gas for any purpose. Transport was therefore a "no-go" area for us. However, I knew that we did have a problem on the horizon with replacing our aging gasholders and that one of the solutions envisaged was storage at relatively modest pressures of 5-8 bar[1] in so-called bullets, or large pressure cylinders. Clearly, if these were full of suitably adsorbent material, they would hold a lot more gas, so I was able to say honestly that we might have a possible interest.

Frank then went on to say that he had been invited to a meeting in Atlanta, Georgia to discuss the enlargement of an existing programme and they would be delighted to have BG included in it. So off I went and put the proposal to one of the London Research Station's Directors, Grev Gibson, to sell him the idea. Grev was always keen on anything that was really novel and he got very enthusiastic about this ANG project. Somewhat to my surprise then, he got approval for me to go to this meeting.

[1] 0.5-0.8 MPa for SI zealots. I offer in my defence that the bar is a much more practical unit and one approved by the International Gas Union.

Even more to my surprise, I was allowed to fly Business Class, a first for me, as Frank was travelling thus as being a director of his firm. Frank filled me in on some of the past history of ANG during the flight. A number of US organisations had had a nibble at the problem, including the Ford Motor Co. The impetus for the programme came from the desire to use natural gas as a transport fuel. It was cheap, clean and relatively non-polluting. The big drawback was, and for that matter still is, on-board storage. Existing vehicles used Compressed Natural Gas (CNG) but to store anything comparable with the energy in a gasoline tank, it was necessary to use very high storage pressures, around 200-250 bar, and as you must realise, this required large and very heavy cylinders. If comparable amounts could be stored at much lower pressures, say 30-35 bar, by using an adsorbent, the advantages were clear. Active carbon was the material of choice, because the problem was to pack in as much per unit *volume* of adsorbent as possible. The adsorption was done at ambient temperatures and thus adsorption took place solely in the nanopores of from 1-2 nm diameter. All other pores were of no use because unlike most of the adsorption processes that had been studied, the adsorption temperatures were well above the critical temperature of methane, the principal constituent of natural gas. Consequently, no incipient condensation could occur in mesopores and only the London dispersion forces operated during this adsorption process. Active carbon had the advantage over other potential adsorbents that it could be tailored relatively easily to maximise the number of nanopores: the trick was to avoid creating more meso- and macro-pores in the process. This is where his firm came in, as they had a US subsidiary and this was already partially involved in the ANG programme. The group we were going to meet was called, somewhat improbably, AGLARG. As Frank said, it sounded like something from the planet Zorg but it actually stood for Atlanta Gas Light Adsorption Research Group.

The next day we met the existing members of the group. The chairman and driving force behind the project was Doug Horne of the Atlanta Gas Light Co. Other gas utilities present, Pacific Gas and Electricity Co, Public Service Company and Northern Indiana Public Service Company were also original members. The reason that the meeting had been called lay in a call for proposals by the Gas Research Institute (GRI) of Chicago. A slight explanation may be in order here. GRI was funded by a levy on the gas sales of the various US gas utilities and its purpose, as the name implies, was to promote research into matters of common interest to the US gas industry. As you may imagine, paying this levy was akin to pulling back teeth for most companies and they were keen to see a return for the money extracted from them so painfully. The situation was made more complicated by the fact that the Federal government regulated the price of gas sold from State to State, although not within one, so they had a finger in the pie of the direction of the research programme as well. GRI, unlike BG, had very little research that it did directly: almost all was contracted out under the control of GRI managers. I think this little diversion is worth telling you because I was unaware of it and it helps explain what subsequently happened at this inaugural meeting.

In addition to the original members, Frank and I represented our own companies, and there were representatives also invited from the Consumers Gas Co of Toronto, which had a very active programme of CNG for use by their customers. Doug quickly put us in the picture. AGLARG and its predecessor, Future Fuels Inc., had worked on ANG for road transport over the past few years at a fairly low level, none of the companies involved having much in the way of a research budget anyway. They had adopted a working pressure of 500 psia[2] as a practical one, because it was the highest pressure that a simple single-stage compressor for home use could reach (and also a nice round number) but one that provided the potential for worth-while amounts of gas to be stored. How much could be stored was the point at issue. The best work up until now had managed up to 100 volumes of gas (at STP of course) per volume of carbon. A reasonable target and one that would give commercial credibility to the work was considered as 150 v/v. I got the impression that this figure was pulled out of the air to some extent and there was a bit of a bidding war going on between

[2] 34 bar (3.4 MPa). We in BG were fairly well metricated by this time whereas the USA was the last stronghold of Imperial measures. Ironic or what?

different groups working on ANG and AGLARG obviously felt that they couldn't be left behind in the race.

The technical support behind this project rested almost entirely on the shoulders of David Quinn, whom I met for the first time at this meeting. We were to become close collaborators in the future. David was based at the Royal Canadian Military College of Science at Kingston, Ontario where Prof. S.S. Barton had worked on active carbon for many years with Canadian Government money. David had to some extent inherited his mantle and worked under contract from AGLARG to produce novel carbons that would meet this 150 v/v target that he felt was achievable. I got the impression that when he, I and Frank got together at the coffee break that he was delighted to have someone he could talk to at the same level, no-one in the AGLARG committee having anything like our technical insight into the physico-chemical problems involved. Not that I had much at this time, although I did know a bit about carbon as an adsorbent but I was certainly to learn much more and very quickly too.

The group that was missing from the meeting so far was that from GRI. It turned out that they were late because they got caught up in a Martin Luther King parade that took place all down the main street. King had been based at Atlanta, so it was reasonable that they should make a big thing of his memorial day. The delay was actually very useful, because it became clear during the earlier exposition to Frank and me that AGLARG were not best pleased with GRI who had apparently gone back on a previous expression of support and had got involved with another group instead, who were apparently waving round even bigger numbers than 150 v/v under GRI's nose. When the three GRI representatives arrived, they had a warm welcome one might say. As a bystander, I was fascinated by the directness with which my future American colleagues pitched into these visitors who must have had a very uncomfortable quarter of an hour. Still, this did clear the air and when the temperature had dropped a bit, it was clear that there was room for some co-operation. It was also clear that none of the GRI people had very much idea of the science behind adsorption at supercritical temperature and as a result, they had perhaps swallowed the claims of certain competitors of ours rather too easily. As an aside, I would comment that this is a major problem when all your research is contracted-out. If you haven't got your own experts who can monitor the programme with sufficient insight because of their own expertise then you could be led up the garden path, as it were. Here ends the sermon.

During and after lunch, David, Frank and I put our heads together and came up with what we considered the outlines of a viable research programme. We adopted this fabulous figure of 150 vol/vol at 78^0F (25^0C) [3] at a working pressure of 500 psia or 34 bar as a target and, I might say, by the end of the programme, we had reached it. Another figure plucked out of the air again, I suspect, was that the adsorbent should cost no more than $2/lb. I don't think Frank ever believed that was possible and indeed, it was the cost that finally was the arbiter of whether the project was successful or not. In the afternoon, peace broke out and it was agreed that all the organisations present should take part on an equal footing with an agreed contribution, either financial or in research effort or a mixture of both. The cash was needed to pay for David's work in Kingston. From GRI's point of view, it was a good deal because for a relatively modest cash contribution, they were part of quite a big and well-run programme and had much more for it than they could have supported on their own.

After the meeting, David invited me to come and see his laboratory so I contacted the local BA office and changed my itinerary. I had to go to Chicago on other business, for which I already had a ticket, so all I needed to do was to book a return flight from Toronto and buy one for the leg to Toronto from Chicago. I mention this because when I got to Toronto airport finally, the evening BA flight had been cancelled because of snow at Heathrow but I had booked on Air Canada who were better able to cope with the stuff. I stood there smugly in the check-out queue with my ticket in my

[3] Alright, 298K if you insist.

hand while grown men from the cancelled BA flight were tearfully imploring the Air Canada check-in staff to let them aboard, to no avail.

To cut a long story short, this was the start of a very interesting and challenging programme. I think we were all very well matched and complemented each other's strengths. Sutcliffe Speakman provided very useful input on the practical side of making industrial carbons and worked out a way of making coherent, strong shapes that were christened "immobilised" carbons. David Quinn had had years of experience and was able to get some of his ideas put into practice. In particular, he worked on a selectively activated PVDC carbon that was not only extremely strong but enabled us to achieve the 150v/v delivered gas target that we had been set. My group at the LRS was somewhat in between these two poles , in the sense that we had the equipment for rapidly testing all the experimental and developmental carbons that became available but also put on the road a converted road vehicle running on ANG. To an extent, this was the visible output of the project as far as senior managers in BG were concerned but as one of my US colleagues remarked to me "The bosses like to have something they can kick the tyres of". Cynical maybe, but that's the way things go. Doug Horne from Atlanta Gas Light was an enthusiastic and very capable manager of the whole programme. We were unaware only until much later of the excellent work Fred Baker was doing for Westvaco Carbon and which produced a very good rival product to ours[4].

Frank Derbyshire left England to become the Director of the Center for Applied Energy Research at the University of Kentucky and Alan Grint was appointed to fill his place at Sutcliffe Speakman. This was very interesting to us because Alan had come from BP and it soon became clear that the carbon research group in the BP labs. at Sunbury had been here ahead of us in ANG work and had indeed already overcome some of the problems we had encountered. They had dropped the work as being unlikely to bring them a good enough return. Alan in his turn moved on and Steve Ragan took his place and was there when the project finished. As is often the case in industrial research, the technical goals were achieved but the cost was too great to displace the existing technology, CNG. I took my retirement from active research and my final involvement was to write and account of the whole project that we presented to GRI.

Well, you may ask "Did any useful come out of this?" To an extent, the answer has to be no although the use of ANG for gas storage is still an active thread of the work. I was told that WSC, the successor to Sutcliffe Speakman, sold the immobilised briquettes for convenient dispensing of CO_2 in pubs. WSC in turn has now been absorbed into the Calgon group but the briquettes are still advertised on their website. David Quinn's activated PVDC turned out to be ideal for storing the highly toxic gases used for doping semiconductors with Arsenic and other similar elements and has found a niche market there. Despite Sir Denis Rooke's misgivings, the use of CNG for road fuel is developing rapidly, except ironically in the UK, and for environmental reasons, has not yet attracted hydrocarbon tax for this application in EU countries. And who knows, someone, somewhere may blow the dust of my report and realise that this is just what they have been looking for. One can but hope.

Norman Parkyns

[4] Fred presented his work at the Workshop on ANG held at Kingston, Canada in 2001