See (www.iop.org) for further details
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Notes from the Chair

Welcome to all NIG members to this, my fourth and last “Notes from the Chair”. Over the past four years I have been priviliged to lead the Group during a period of growth and an increase in member events, but under IoP rules I have to stand down after four years in office. Later in the year a nomination/election process to find my successor will be organised. But in the tradition of retirees, I thought I should do a review of developments during my term of office.

We have run a range of evening lectures covering most of the areas of interest to NIG members from new build of NPP, including SMR, to decommissioning of research reactors and waste disposal. Nuclear data has featured as well as the UK involvement in a European research reactor. And the application of nuclear materials to medicine was not forgotten: the needs of operation were considered in a talk on radiation damage in graphite and the space industry use of nuclear batteries was also covered.

This last year has seen the NIG start to hold longer events. Initially, the main events were evening lectures, but in some cases these were not well attended and we understand the difficulties and costs of travelling for shorter events. So we decided to try something a little different. In October last year we held a seminar, jointly with the History of Physics Group, to mark the end of Magnox generation (see later for a report on this seminar). This took place at Wylfa and we were extremely pleased to have 120 attendees. Not all were IoP members, but it was, in fact, the only public meeting to mark this event. In July we had a seminar on Geological Disposal of radioactive waste at Warrington. This was also well attended full, with over 90 attendees who were able to gain an insight into this important area (also see later for a report on the seminar).

Internally, the NIG now has a new secretary, Zahid Riaz, who had been a committee member for two years. We have one new committee member, David Weaver, and we are pleased to welcome him – his pen picture is later in the Newsletter. Just as important as the three Officers is the whole committee: some members have responsibility for certain roles: Newsletter editor (Heather Beaumont – where would we be without her?); Communications (Claire Elliott – another essential part of the NIG); Social media (Dale McQueen is running the Facebook account and Chris O’Leary is monitoring LinkedIn); other committee members have organised events and all have contributed in myriad other ways. Without an active committee the NIG would not run smoothly and be a vibrant organisation.

Relations with the Nuclear Institute have developed and there is a financial gain for anyone who is a member of both the NI and IoP (see later). We are exploring the potential for joint events and we have had NI support for some already.

In past years we have published articles in the Newsletter on gaining chartered status and mentoring as well as reporting on the events we have run. Most talks have been uploaded onto the web, with the presenters’ permission. In this edition, we break new ground with two articles on the early history of nuclear research in the UK (the editor will be interested to hear if such items are of interest to members).

So overall, I think I can look back on my term of office with some degree of pleasure at what we have managed to do. But I must record my personal thanks to all the committee members and officers who have been in post during my time as Chairman – you have been unfailingly supportive and carried out your roles with enthusiasm. It has been a pleasure to work with you all and I couldn’t have done the job without you.

Finally, as has become traditional in my Notes, I should comment on progress on Hinkley Point C. As you know doubt know from the press coverage, after a few humps and a little uncertainty at the end due to the concerns of the new government, the agreement to go ahead has been agreed. The planned date for operation of the first of two EPR reactors is 2025. Both the Advanced BWR and AP1000 designs are in the final stages of the regulatory approval process and Horizon and
NuGeneration respectively also plan for first power in about the same timeframe. So if all goes well, we will have at least one new nuclear power station operating in the mid-2020s.

I feel that the NIG has now established itself – we have over 800 members – and with I am sure that the new chairman/woman will be supported by the committee as I have been and that the NIG will flourish in the future.

Good wishes to him/her, the committee and all NIG members in your future careers.

Geoff Vaughan
Chairman
IOP Nuclear Industry Group

Nuclear Industry Group Prizes 2016

The Nuclear Industry Group was pleased to award an Early Career Prize and a Career Contribution Prize in 2016. Selecting the prize winners this year was again a difficult decision as the calibre of the entrants was very high.

Early Career Prize

We are delighted to announce that this year’s prize was awarded to as Rebecca Houghton of Sellafield Ltd. Rebecca is a relatively new entrant to the UK nuclear industry, having recently completed the Sellafield Ltd graduate scheme. Despite this, she has already made a significant contribution to the industry during her secondment to the Nuclear Decommissioning Authority.

Her work there formed a key contribution to the strategic direction to be proposed by the NDA to the Department for Energy and Climate Change for managing radioactive material stockpiles.

Career Contribution Prize

The NIG Committee were delighted to award this year’s career contribution prize to Kevin Hesketh of the National Nuclear Laboratory.

Kevin's career in the nuclear industry has spanned over 40 years and many varied technical areas. He has supported a wide range of UK and European initiatives and activities, contributing his extensive knowledge to many important expert groups, such as the OECD Nuclear Energy Agency (NEA) group and the Nuclear Science Committee.

Kevin also sits on several NEA technical committees in its nuclear science area and is currently chair of two (Working Party on the Scientific Issues of Reactor Physics and Expert Group on Very High Burn-ups in LWRs).

During his extensive career, Kevin has authored or co-authored over 200 reports and publications. Kevin is an honorary professor at both the University of Manchester and the University of Birmingham.

Kevin and Rebecca are worthy winners of their prizes and were presented with their certificates at the Group event at EDF Energy in Barnwood.
The calling notice for the 2017 Nuclear Industry Group prizes will be released later this year. The deadline for submissions will be 31 January 2017.

The photos show Prize Committee Chairman (and Group treasurer) Chris O’Leary presenting the winners with their prizes.

**Committee Elections**

As mentioned in the Notes from the Chair, a new Chairman/woman needs to be appointed this year as four years is the maximum in an Officer role. However, the incumbents can stand again for the committee, as ordinary members can serve in total for 12 years.

**Chair position**

The basic requirement of the NIG Chairman/woman is to ensure that the committee runs effectively and efficiently for the benefit of the Group’s members. As any chairman/woman will tell you, the role is to some extent created by the post-holder who has to determine how he/she will carry them out.

The activities that need to be overseen include:

- Ensuring that committee meetings are held as appropriate and chairing them,
- Ensuring an adequate and interesting programme of lectures, visits and other events is organised for group members,
- Ensuring advertising for the above,
- Ensuring the annual prizes are advertised and awarded to suitable recipients,
- Ensuring the annual Newsletter is produced,
- Ensuring nominations and elections for committee places are held in a timely manner and as appropriate,
- Interacting with IoP on Group activities attending the Group Officers Forum (twice a year, but this can be shared with other officers),
- Interacting with other IoP Groups on areas of common interest and organising joint meetings,
- Interacting with relevant groups and organisations outside the IoP such as the Nuclear Institute,
- Considering requests for funding from conference organisers etc,
- Responding to requests from IoP to comment on various issues and consultations, and
- The IoP has recently determined that only the chairman/woman’s contact details will be provided on the IoP website (Data Confidentiality apparently), so all enquiries about the Group will be channelled to the post holder.

During tenure of the current Chairman, Geoff Vaughan, many of the above were in fact carried out by other members of the committee and generally discussed at committee before a decision is made, although there were times or situations where he got involved as an individual and made decisions. Clearly a new Chairman may decide to do things differently.

Geoff Vaughan was elected into this role in October 2012 and so it becomes open for applications again for November 2016. To be eligible for nomination as Honorary Chair a person must be a corporate member of the Institute (MInstP, FInstP, HonFInstP) and a member of the group. They should also be proposed and seconded by group members (committee members may act as proposers / seconders).

A calling notice has been issued to all NIG members shortly including details of how to apply. The closing date for nominations will be 18 October 2016. Once the nominations have been received an election will be held if necessary.
Meet the new Committee Member

Following elections last year the Nuclear Industry Group welcomes Professor David Weaver as a new committee member. Below, David tells us a bit about himself.

My interest in nuclear power technology was first confirmed by attending a UKAEA Production Group 6th form “Short Works Course”. Following my degree in Natural Sciences, I transferred to the University of Birmingham to do a PhD incorporating the Reactor Physics MSc course. After 18 months as a Commonwealth Scholar in Canada I returned to work on the Birmingham campus.

In 1986 I took on stewardship of the Physics and Technology of Nuclear Reactors (PTNR) MSc Course at the University of Birmingham. Together with the department and contacts in the nuclear industry, we were able to persuade a consortium of companies to sponsor the course at a time of low public and government support. Overcoming this challenge proved key, as the PTNR course was, for a time, the only UK university course supplying trained Masters students to the industry. I am pleased to say the PTNR course has thrived and its strong reputation continues.

Following an early retirement, I continued to support the PTNR MSc by lecturing until recently and have also used my retirement to undertake a number of consultancy projects for both the UK nuclear industry and the Nuclear Energy Agency. I continue to sit on a number of advisory committees.

Within the Institute of Physics I have been Secretary and Chair of the Midland Branch and served as a Vice-President for (i) Regional and Public Affairs and (ii) Services for Members. I have also been a member of committees of the BNES/Nuclear Institute.

Group Membership

The Nuclear Industry Group began in 2009 and became one of the fastest growing of the IOP groups. We now have 825 members which puts us in the top 10 groups (of 48) by size.

We have recently cross-referenced Group data membership with IOP branch membership to give us some perspective on the geographical locations of the membership and to help us better understand how we can serve the membership.

<table>
<thead>
<tr>
<th>Branch</th>
<th>Members</th>
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<tbody>
<tr>
<td>Manchester and District</td>
<td>85</td>
</tr>
<tr>
<td>Lancashire and Cumbria</td>
<td>70</td>
</tr>
<tr>
<td>Merseyside</td>
<td>73</td>
</tr>
<tr>
<td>East Anglia</td>
<td>34</td>
</tr>
<tr>
<td>London and South East</td>
<td>159</td>
</tr>
<tr>
<td>South Western</td>
<td>126</td>
</tr>
<tr>
<td>South Central</td>
<td>46</td>
</tr>
<tr>
<td>East Midlands</td>
<td>53</td>
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<td>West Midlands</td>
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<td>North East</td>
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<td>Scotland</td>
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<td>Wales</td>
<td>31</td>
</tr>
<tr>
<td>Ireland</td>
<td>18</td>
</tr>
</tbody>
</table>

We can see that 28% of our membership is based in the North West and a further 23% in the South East and 21% in the Central and South West regions. The remaining, but no less important membership, is based across the
midlands, north east and in Scotland, Wales and Ireland. We are keen to give all members the opportunity to participate in NIG activities and attend events, so if you are located in a region where we have not held an event and you believe there would be sufficient interest then please do get in touch with the Group and put forward your suggestions.

IOP Groups Committee

The IoP Groups Committee manages the structure and operation of Groups under delegated authority from the Science and Innovation Committee.

The Groups Committee has the following responsibilities and powers:

- The creation, merger and closure of groups
- To ensure that the portfolio of groups accurately reflects current and emerging physics activities
- To monitor the activities of groups, including their use of funds
- To allocate resources to groups according to the budget set by Council
- To arrange elections for membership of Groups Committee
- To work with the IOP’s conference team to agree operational matters concerning conference organisation
- To ensure that all group activity is consistent with the diversity and inclusion policies agreed by Council
- To advise on matters pertaining to groups and on mechanisms to deal with policy decisions

The Chair is appointed by Council but members through nomination and, if necessary, election. Only Group Officers (ie Chair, Treasurer or Secretary) are eligible to join the Groups Committee and can serve for up to four years.

The Nuclear Industry Group’s Honorary Treasurer, Chris O’Leary, was elected to the committee in October 2014 and will therefore serve until October 2018.

The Groups Committee offers an excellent platform to get involved with other IOP initiatives.

In this issue of the Newsletter, Chris discusses three initiatives he has supported in 2016.

IOP ‘Developing a Contemporary Membership’ Workshop

This was a one-day event held in central London on 7 March 2016, facilitated by the IOP and with attendance from a broad spectrum of people across its four main constituency groups: academics, teachers, physicists in industry and students/ early career researchers. It was attended on behalf of the NIG by Chris O’Leary.

‘Technicians’, a group not currently represented by the IOP, were also present to express how they thought they could contribute to the community. The subtitle for the meeting was ‘Inclusive/Relevant/Valued’, which summarised the meeting’s goals for adapting its membership offering. Feedback from the meeting by each stakeholder group was:

- Academics said that IOP membership is important “because a united physics community is a stronger physics community”
- Teachers reflected that “it brings you into the diverse and respected family of physics. Involvement opens up potential”
- Industry recognised IOP “gives you the capability to do the physics job, gives peer recognition with well-developed networks helping not just industry but also science”
- For students and early career physicists, IOP “keeps us at the heart of the physics community”
- Technicians spoke of there being “more than one way to be a physicist” and their desire to contribute to the community
The challenge addressed by these groups throughout the day, mainly through think-tanking exercises in segregated teams, was how to make the IOP membership structure attractive and relevant to all, throughout members’ careers.

Broadly, the outcome was a proposal to reduce the grades of membership from six to three: one for Members, one for Fellows (to represent those who are leaders in whichever physics-based career they have pursued) and one for Honorary Fellows, to continue to recognise exceptional services to physics or the IOP.

IOP Bursaries

Did you know that the IOP have recently launched an exciting new bursary for early career researchers? These are available for group members only. Please see the list below for some of the bursaries currently offered to IOP group members.

• **Early Career Researchers Fund** - financial support of up to £300 is available for early career researchers to attend international meetings and visit international facilities. It is worth noting that support for “early researchers” to attend conferences etc. extends to first 5 years of paid employment.

• **Research Student Conference Fund** - financial support of up to £300 is available for PhD students who are Associate Members of the Institute to attend international meetings and major national meetings.

• **C R Barber Trust** - grants of up to £300 are available for research students who are Associate Members of the Institute to attend overseas conferences.

• **Virdee Grant** - small grants (£500 to £2,000) or a single grant up to £5,000 in 2016 are available for members of the physics community based in the UK and Ireland to undertake activities that will support the development of science and technology in sub-Saharan Africa.

For a full list of IOP grants please visit the [website](#).

Physics 2020

The IOP is piloting a new programme, Physics 2020, which aims to develop a robust evidence base about physics in the UK to find out how it can best support the discipline and its members.

The IOP Groups are seen as the key enabler for this. There are two parts to this programme:

1. Physics Landscape: Developing interactive data visualisations intended to display information about physics in the UK
2. Discovery Roadmaps: Work with the groups to look in detail at specific parts of the discipline and identify key challenges to inform IOP activity. In this initial pilot study, IOP are planning to focus on utilising open source data (such as that available from RCUK and the Intellectual Property Office) to develop visualisations

Chris O’Leary, the NIG treasurer has attended these meetings on behalf of the group. His involvement to date has been through support to two, one-day workshops, in early July.

The first day was about the development of a ‘roadmapping’ methodology for use by each group. This was attended by Anne Crean (IOP Head of Science & Innovation); Johnathan Everett (IOP Knowledge Exchange Manager) and Chris; with facilitation by Dr Michèle Routley of the Institute of Manufacturing (IfM). Dr Routley provides consultancy and training in the type of strategic roadmapping techniques advocated by the IfM (e.g. see [www.ifm.eng.cam.ac.uk/roadmapping/research/](http://www.ifm.eng.cam.ac.uk/roadmapping/research/)).

A series of think-tanking exercises where undertaken to develop a structure that the attendees felt would work for most groups, and enable them (with support from the IOP) to strategically map-out their field for the next decade.
The second day had attendance from the broader working party that IOP has assembled to develop to steer Physics 2020; mainly IOP Group Officers but also some independent experts (e.g. the ex-CEO of EPSRC). This workshop was focussed on a ‘taxonomy’ exercise. The organisations whose data IOP are planning to use have different taxonomies, so IOP needs to develop its own taxonomy, linked to these existing taxonomies, that will enable data to be displayed in a uniform manner that makes sense to the physics community.

The pilot studies are expected to be complete by October 2016, ie in time for the Group Officers Forum later in November.

Relations with the Nuclear Institute

Over the last year the IoP, and the NIG, have been discussing closer co-operation with the Nuclear Institute. As a result, if you are member of both IoP and NI you can claim a reduction of 25% on both membership fees. The route is to send information on your NI membership to the IoP membership department. To claim from the NI, there is a form to fill in which they will supply. Please note that there is no rebate on fees already paid, but the reduction will apply from your next payment.

We are also attempting to ensure that each organisation keeps the other informed of events that it is sponsoring. This will in fact include other organisations, as NI is considering setting up a Co-ordination Committee on which the NIG will be represented. The potential for joint sponsored events is also being investigated.

Finally, we are sure all NIG members wish to congratulate one of our committee members, Neil Thomson, who has become the President of the NI. (Neil is also a member of the Council of the IoPi)

Presentation Series on the Nuclear Fuel Cycle

For those people who have an interest in the Nuclear Fuel Cycle a presentation series by Peter Wilson has been made available on videos to NNL’s youtube channel. Dr Peter Wilson is the author of The Nuclear Fuel Cycle.

Peter prepared a series of presentations based on his book and his experience in the nuclear industry.

You can access Peter’s presentations by clicking on the links below: Each presentation lasts for 30 – 40 minutes.

Introduction - Introduction - Personal introduction from Peter Wilson; how and why the material came to be presented.

Chapter 1 - Basic principles - Explanation for a non-technical audience of the science underlying the nuclear industry.

Chapter 2 - Reactors - What the various types of civil power reactor have in common and how they differ.

Chapter 3 - Fuel manufacture - converting uranium ore into fuel for various kinds of reactor.

Chapter 4 - Reprocessing - separating fuel discharged from reactors into potentially useful material and genuine waste.

Chapter 5 - Advanced issues - suggestions for reducing perceived dangers of weapon proliferation, in reactor control or in waste management.

Disclaimer: This set of presentations were not produced by the NIG which does not guarantee the accuracy of any of the content.

UKAEA Culcheth

Geoff Vaughan

Although some people in the nuclear industry may have heard of the Culcheth site of UKAEA, they may not be aware of the important role it played in the research work for nuclear reactors.
The Reactor Materials Laboratory (RML) was established at Culcheth in 1950, located between Manchester and Warrington in Lancashire, and about three miles from the better known Risley site.

When I began my association with the site in 1974, most of the research had finished and the authority’s Safety and Reliability Directorate was the main occupier. The work was split at this time between support for the MoD’s naval reactors and safety analyses on the UKAEA’s research reactors and the UK’s civil reactors. I knew nothing of the history of the site, but was aware that some research continued in what we knew as the Mayfair Labs - I well remember seeing people in white coveralls and face masks walking on the roof with radiation detecting equipment. As I was a member of the non-MoD part of the Safety and Reliability Directorate I knew little of what research was being done beyond it being PIE for the Navy.

A little later, the site was used as an overnight stopping place for material being taken from Dounreay to Winfrith for PIE, as it was surrounded by a security fence. My wife overheard some mothers outside the school saying this was very dangerous and shouldn’t be allowed - clearly they didn’t know the history of the site or that there was an operating reactor at Risley! I wonder what they think about the housing estate which is built on the site now!!

The following two articles have been abridged by Brian Kehoe from his privately printed booklet, The Reactor Materials Laboratory, Culcheth: An Informal History, which another NIG member, and ex-Culcheth worker, gave me. I hope you all find these articles on the history of nuclear power research as interesting as I did.

Geoff Vaughan is the Chairman of the Nuclear Industry Group

Fast Reactor work at Culcheth

Brian Kehoe

When the Culcheth labs were established in 1950, uranium resources were thought to be limited. The fast reactor was regarded as the ideal type of technology for the long term as it would use far less uranium than thermal reactors, as it could 'breed' fissile Pu239 from U238, which could then be used as fuel. Culcheth’s development work during its first ten years was more on fast than on thermal reactor technology. The project was largely done as a very close cooperation between Culcheth and the Fast Reactor Design Office in the UKAEA Industrial Group HQ at Risley.

As the power rating in a fast reactor core is high a liquid metal coolant was thought to be necessary and this threw up many problems: the design and materials for the very highly rated fuel elements, the choice of coolant and the problems for handling the coolant and its compatibility with the cladding and construction materials.

Selection of a refractory metal cladding from the group V, Nb, Ta, Mo, W, Zr was recommended, with a provisional preference for niobium. Culcheth undertook an R&D programme necessary to confirm a final selection. Since none of these metals, except perhaps zirconium, was available in a prefabricated form, the development proposals submitted necessarily included investigations relating to fabrication, welding, alloy optimisation, physical and mechanical properties, acid and aqueous corrosion, and compatibility. This programme, which involved almost every department at Culcheth became a major long-term research programme which in fact complemented and strengthened the more ad hoc activities arising from working on problems facing the factories and design offices.

The candidates for fast reactor coolant were liquid sodium (MP 97 °C), sodium-potassium mixture (NaK) with a lower MP and lithium. Lithium was dropped as its Li-6 isotope had unacceptable nuclear characteristics. All these are very reactive with water and all test work had to be under an inert gas, argon.

The very high power rating of a fast reactor core meant that safety was vital as over-heating could lead to melt down and molten plutonium could pool and go supercritical. An annular fuel element design was adopted for the Dounreay Fast Reactor (DFR), which was an experimental, 20 MWe reactor. This concept employed an inner can which would be penetrated more
readily by molten fuel than the outer. Thus in the event of a severe power/temperature excursion, fuel would be directed down the centre channel and out of the core, obviating the spread of damage to neighbouring elements. The combination of a niobium outer can with a vanadium inner can was advocated on the basis of their known characteristics and laboratory trials. In-reactor exposures, however, demonstrated that vanadium was susceptible to embrittlement and excessive corrosion should the coolant quality deteriorate and this design was abandoned.

Tantalum-coated inner tubes was a variant on the previous proposal, ensuring safety by the same mechanism. A thin tantalum coating on a stainless steel tube, it was shown, would effectively prevent a uranium/steel reaction at temperatures below the melting point of uranium but had zero protective value above that temperature. Thus a tantalum-coated stainless steel inner tube would promote discharge of molten fuel via the centre channel in combination with a niobium outer can. The concept seemed promising. Stainless steel tubes heated by the passage through them of an atmosphere of TaCl5 or TaI5 vapour acquired a thin impermeable tantalum coating in trials at Culcheth. These tubes were made up into miniature fuel elements and failed as intended at 1100 °C when tested to destruction in the laboratory. Scaling up of the Ta deposition process in a production plant, however, revealed process and quality control problems which made the concept untenable.

Laboratory investigations at Culcheth showed that the more reactive refractory metals, vanadium, niobium and zirconium, became embrittled by the uptake of oxygen and nitrogen at high temperatures, so that hot working processes were not an option with these metals. Another scheme was to use stainless steel with a thin impermeable tantalum coating. This seemed very promising at one stage but quality control problems eventually ruled out its use.

Ultimately, the induced inner tube failure principle was adopted by way of an elegant design solution. Coolant flow was so distributed between the inner and outer channels that the inner clad would always run hotter and tend to fail first. The culmination of all the design and testing work was to be the experimental Dounreay Fast Reactor (DFR) which had downward flowing NaK as the coolant and niobium as fuel cladding. DFR, was operated from 1956 and was the first fast reactor to feed electricity into a grid. The assessment of different cladding materials took up much Culcheth effort and testing in the sodium loops. Many refractory metals it was found were embrittled by quite low levels of oxygen and/or nitrogen in the hot, flowing sodium. The liquid metal work was initially conducted in the physical metallurgy laboratory but when pumped test loops were introduced in 1955 the work was moved to a shed-like brick-built structure, known to some as Rose Cottage, well away from the other laboratory buildings because of the fire hazard. When more and larger pumped loops were needed for testing under conditions expected in the planned PFR (Prototype Fast Reactor) the work was moved to a third location, a building called Haymarket, which was one of the typical H-block structures left over from when the site had been a WW2 hostel.

In 1956 and 1957 many of the Culcheth scientists were transferred to Dounreay to continue their work there which continued with the construction of the 300 MW Prototype Fast Reactor (PFR) though the hot test loop work continued at Culcheth. To complete the story it should be said that by the mid-1960s thermal reactors were gaining ground with the construction of the Calder Hall, Chapelcross and early CEGB Magnox reactors. The DFR was closed down in 1977. The PFR had upward flowing sodium coolant with steel fuel cladding. It was completed and commissioned in 1975 and fed 250 MW to the grid. However, metallurgical and liquid metal problems were considerable. The PFR was therefore finally closed down in 1994.

Thus ended the British love affair with fast breeder reactors.

Brian Kehoe is retired.
Graphite – Its development for Nuclear Power Reactors

Brian Kehoe

In the late 1940s Britain decided to develop the nuclear bomb and for this it would need U235 or Plutonium-239. The latter would need a nuclear reactor to breed the Pu-239 from U-238 and the reactor technology chosen involved uranium metal rods as the fuel, graphite as the moderator and air as the coolant. Hence the two nuclear reactors (the Windscale piles).

Their development led to the idea of using pressurised carbon dioxide as the coolant and using it to raise steam for turbines and electricity production. This led to the programme “Magnox” reactors (see Farewell to Magnox later in this Newsletter). The first Magnox reactors were built to both produce plutonium as well as electricity: but the majority were operated by the utilities (Central Electric Generating Board [CEGB] and South of Scotland Electrical Board [SSEB]) purely for electrical generation. In all 18 Magnox reactors were built in the UK. The Magnox designs led on to the Advanced Gas-cooled Reactor (AGR) designs which used enriched uranium dioxide fuel and ran at somewhat higher temperatures with greater thermal efficiency. 14 AGRs were built.

These developments all raised enormous physical, chemical and metallurgical questions and problems needing urgent solutions; some of which was done at the Culcheth laboratories.

In a graphite moderated reactor, neutron collisions lead to carbon atom displacement from their normal crystal lattice positions. Most displaced atoms quickly recombine with vacancies or settle at crystal boundaries but others lie in interstitial positions where their potential energy is higher than normal.

At the normal operating temperatures of the air-cooled Windscale Piles (under 150 °C) these interstitial atoms accumulate in the graphite along with vacancies, and the energy (Wigner energy) latent in the graphite rises. This was foreseen as a potential problem, and every six months or so the reactor operators would conduct a ‘Wigner energy release’ to prevent the stored energy rising too high. This involved allowing the core temperature to rise toward 300 °C under carefully monitored and controlled conditions when the graphite would anneal, that is, the majority of the interstitial atoms would migrate to normal crystal lattice positions, releasing stored energy. This produced a further temporary rise in the temperature of the core which was controlled by the operators.

In a Wigner energy release in October 1957 the temperature rose too high in parts of the core and some fuel cartridges overheated. This resulted in a fire which was finally extinguished with water, but not before the dispersal of significant fission product contamination, particularly radioactive iodine, across wide areas of Cumberland. The ‘Windscale accident’ as it became known had widespread implications for the future of the nuclear industry and had an impact on the work at Culcheth.

The displacement of carbon atoms also produces changes in the dimensional, physical, and mechanical properties of the graphite components of the reactor core. In reactors using CO\textsubscript{2} as the coolant, these properties are also changed by chemical reactions involving the CO\textsubscript{2}.

With two Magnox reactors in operation at Calder Hall, two more and four at Chapelcross under construction, and a civil programme envisaged, it was clear that more needed to be learned about the physical properties of graphite and the effects of irradiation. Existing UKAEA programmes to study the behaviour of the reactor graphites, including a monitoring programme using graphite samples irradiated in the Windscale and Calder reactor cores for the purpose, were enhanced and accelerated by an expanding team at Windscale in collaboration with a group at Harwell and then at Culcheth.

Up to that time the graphite moderators of these reactors were built using graphites developed mainly for use as electrodes in industrial applications. So Culcheth installed a small scale processing unit for studying the effect of impregnation on the density and in-pile oxidation of the available graphites. Facilities were added for manufacturing different graphites for a detailed study to find the best materials for reactor use. Crushers, grinders and ball mills were installed to reduce coke down to a suitable powder form; binder was mixed in at a suitable temperature. A 150 ton extrusion press and 50 ton moulding press could then form the wanted test pieces that were carbonised.
impregnated if desired with tars or pitches, and then graphitised at around 3000 °C.

A factor underlying much of this work was that as well as being the moderator, graphite was a significant structural material. It was recognised as necessary to establish that, over the life of a graphite moderated reactor, irradiation and the extent of CO₂ coolant attack would not unduly weaken the graphite or otherwise affect its function to an unacceptable extent. The same considerations applied to the graphite to be used in the AGRs as the moderator but also as a structural material in the fuel elements where it forms a double sleeve surrounding the fuel pins.

The temperature of the graphite in the Calder and Chapelcross reactors was much higher than in the Windscale reactors and the storage of Wigner energy was not expected to be a problem. However, the dimensional changes and porosity increases which graphite might undergo during many years of neutron irradiation were of concern, particularly in the civil Magnox reactors whose construction was soon to start.

Variations in thermal conductivity were also of potential concern, particularly for graphite irradiated at lower temperatures, while the behaviour of the thermal expansion coefficient under irradiation provided crucial information about the underlying structural changes in graphite and helped predict dimensional changes.

In the aftermath of the Windscale fire, work on graphite was much increased, and methods of measuring the physical properties of unirradiated graphite were developed. Extruded bricks supplied by both of the major British manufacturers were examined to assess their properties. The work included a survey of normal production blocks and also blocks from experimental manufacturing trials.

Irradiation tests were undertaken on samples of several different commercial graphites. They were studied under fast neutron irradiation at various temperatures. There was a wide programme of work to help guide the choice of graphite for the later Magnox reactors, and this ultimately contributed to the development of optimised graphites for the AGR reactors.

These irradiation studies were all managed by the physicists at Culcheth and Harwell with the irradiation undertaken in materials testing reactors at Harwell, at Dounreay, in one of the Calder reactors, and overseas in Denmark and Belgium. In all these reactors the graphite physics specimens were irradiated inside specially designed hollow fuel elements. The irradiated samples were mostly brought back to Culcheth and Harwell for tests and measurements in the shielded facilities while some low dose samples were measured in Denmark.

Different neutron energy distributions, neutron dose rates and temperature all influence the effect of irradiation on graphite and it was necessary to ensure that irradiations in one facility could be related to those in another, and to conditions in, or to be expected in, a power reactor. Equivalence of both irradiation dose and temperature had to be established. It had been predicted that two parameters representing the neutron flux spectrum and its intensity together with the local temperature were sufficient to characterise the damaging effect of a given reactor location and the Culcheth team confirmed this model using irradiation experiments particularly in Denmark and applying the knowledge to a wide range of irradiation environments. A significant effort was thus expended in conjunction with Harwell to improve predictions of the damaging capabilities of the neutron fluxes in different facilities and reactors, existing and proposed.

The intercalibration of the various existing facilities allowed fast neutron doses to be expressed on a standard scale based on the so-called 'Nickel flux' in a particular position in the DIDO reactor at Harwell. They were then known as equivalent doses and any reactor facility could, in principle, be used as the standard for equivalence.

In the earlier irradiations, nickel monitors were used to measure fast neutron dose, but cobalt monitors were also used to measure thermal neutron dose and allowed a correction to be applied for the burn-up of the irradiation produced isomer of nickel. This correction became very significant in high dose irradiations and iron-54 monitors were developed to replace nickel.

Over time, the emphasis of the irradiation work changed from obtaining more information on stored energy, including irradiation and thermal annealing data, to the more detailed study of dimensional and physical property changes and
extending these studies to the highest achievable fast neutron doses.

Differential dimensional changes across the blocks which make up a reactor core would lead to the build up of internal stresses, which could cause the development of cracks unless the phenomenon known as irradiation creep under the neutron flux was sufficient to relax these stresses and irradiation creep under both compressive and tensile stresses was studied.

Strength changes caused by fast neutron damage were determined. It was also important to establish the effect of radiolytic corrosion, and the high gamma flux of BR2 was used to provide accelerated rates of radiolytic oxidation in CO₂ to determine strength and physical property data on specimens with very high weight loss. At high temperatures CO₂ percolates into the graphite blocks and erodes them by oxidation and the Culcheth chemical department discovered that the effect could be greatly reduced by the addition of a small amount of methane to the coolant gas. Even so, graphite erosion over many years has proved to be very significant in the Magnox stations and the AGRs.

The approach to understanding the dimensional changes of different polycrystalline graphites was based on understanding those of the component crystals and the structural characteristics (distribution of crystal orientations and porosity) of the individual graphites. Highly oriented pyrolytic graphite was included as a good indicator of crystal behaviour in many of the irradiations.

Again, studies on the effect of exposing unirradiated and irradiated graphites to bromium and sodium showed a very good correlation with thermal expansion coefficient. Observation of growth of up to 2% on unirradiated material and more on irradiated double caming of graphite ‘absorber’ rods in the Prototype Fast Reactor (PFR).

The graphite specification developed in 1950 only covered neutron cross-section and density and electrical resistivity. The Culcheth work showed that the graphite manufacturing process affected physical properties and a revised specification was needed, especially to avoid the dimensional change behaviour of the anisotropic graphite which made it unsuitable for use in the proposed AGR programme. The increased understanding of the irradiation behaviour led to the specification of a high thermal expansion isotropic graphite for AGRs. Small samples of these were made at Culcheth for testing, and subsequently trial bricks were supplied by the two British manufacturers.

Eventually, production graphites were irradiated and the wealth of data obtained, with the theoretical understanding of the irradiation induced changes, led to the formulation of engineering design rules for all the important properties. These were vital in 1964 when CEGB and SSEB decided to go ahead with the AGR system for their second phase of reactor construction.

An important feature of all the irradiation programmes was the continuing need to reduce the size of experimental samples in order to allow a greater number of specimens to be irradiated in the ever smaller volumes available inside in the irradiation rigs used for insertion in the highest available neutron fluxes in the various facilities used. The earliest studies used specimens measured in inches but later work was undertaken on specimens measured in fractions of an inch (for the younger readers 1 inch is 2.54 cm). This was particularly challenging for the measurement of thermal conductivity changes. Lasers were a very new development at this time and their use allowed the development of an innovative technique for measuring thermal diffusivity using a laser as a source of pulsed energy.

While graphite dominated the physics teams’ work other materials involved in the construction of the British reactors were also studied. Two examples will suffice: concrete to be used in power reactor containment vessels and for which dimensional changes and creep could be important. A second material studied was glass fibre used as insulation in some of the AGRs.

Brian Kehoe is retired
Farewell to Magnox

An event at Wylfa Nuclear Power Station on 28th October 2014 and co-sponsored by the NIG and History of Physics Groups.

Geoff Vauhan

At the end of 2015 electricity generation at the Wylfa nuclear power station in North Anglesey, the world’s largest and last Magnox generating station came to an end. The final shutdown marks the end of a chapter of British history that began at Harwell in the late 1940s with the construction of Europe’s first nuclear reactor.

In the 1950s plans to build natural uranium metal fuelled, gas (carbon dioxide) cooled reactors were developed. The fuel cladding was a magnesium non-oxidising alloy called Magnox and reactors of this type took this as the generic name. The first Magnox reactor, Calder Hall, was officially opened by the Queen in 1956. As the reactor produced a lot of heat it was decided this should be converted into electricity and fed into the grid – the first time in the world that a nuclear reactor was connected to a national grid.

The seminar was opened by the present Station Director, Stuart Law, who said that the closure of Wylfa 1 should not be seen as the end of nuclear power, which is needed for the UK as a source of carbon-free electricity. After welcomes from the Chairs of the two Groups, Geoff Vaughan and Ted Davies respectively, the seminar began with a historical review by Malcolm Grimston.

Malcolm said his remit was to describe the history of how the UK arrived at the Magnox design and he began with Democritus! Giving examples of early uses of radiation for mainly medical equipment, he pointed out that radiation was in the early years of the 20th century thought to be beneficial to the point where the American medical association refused to approve radium devices unless they could be proven to be given a minimum amount of radiation. However by the nineteen thirties, as the knowledge about the possibilities of nuclear energy, military and civil, increased, the dangers of radiation became more well-known.

After the Second World War, the UK started its own weapons programme but due to the lack of a suitable remote site chose air cooling of the reactor rather than water as the Americans had done, due to the safety issues of losing water. The Magnox design was developed to produce plutonium for the nuclear weapons when it was found that the air-cooled Windscale Piles were not as productive as had been hoped. Due to the lack of enriched uranium, the reactors used natural uranium with graphite as the moderator needed to thermalise the neutrons to enhance the fission cross-sections. The use of carbon dioxide was an improvement also as it reduced chemical interactions in the core. His final comments were on the effects of the Windscale Piles fire (which happened a year after the opening of Calder Hall) on subsequent reactor designs.
Bob McKenzie then took up the story of the Magnox fuel. He described the early production methods and showed some old films of the Springfield site where the fuel was made. The metal was cast as rods which were then placed in the Magnox canning and by pressure, squeezed together. The story was not so simple as the designs of the fuel elements changed as the years unfolded with the intention of improving heat transfer and the lifetime of the elements. This led to long rods, short rods, fat rods and thin rods and some with graphite sleeves - which meant that the production system was never able to gain the advantages of mass production and involved a large amount of manual intervention; though eventually over 5½ million fuel elements were produced. The last Magnox element was produced in 2006 and since then the reactors have closed down as fuel ran out. Bob finished by showing the modern, automated production system used for AGR and LWR fuel.

Ted Hopper took the seminar through the evolution of the reactor design as innovation helped the Magnox design to improve thermal efficiency and fuel cycles and evolve from the small units at Calder Hall and Chapelcross to the two large reactors at Wylfa. One safety move was to reduce the stored Wigner energy which had been the prime initiator of the Windscale Fire by graphite sleeves on the fuel element in the early designs. These innovations included the move from steel pressure vessels with ducts to external boilers to pre-stressed concrete pressure vessels with internal boilers, which allowed higher pressures and temperatures and hence better output and improved thermal efficiency. The higher temperatures meant graphite sleeves were not needed in the later reactors. The development of on-load refuelling so that a shutdown, which was of one to two months duration on the first reactors, was not needed improved reactor availability and therefore economics. However, the graphite moderator loses mass due to irradiation and so the later life of the last two stations it was necessary to use slightly enriched fuel. Eventually to give Wylfa 1 a slightly longer life the partially burnt-up fuel from Wylfa 2 was transferred.

After a coffee break, Bob Clayton gave a talk about a specific Wylfa issue: the first once-through boilers used on a UK nuclear reactor. The boilers were fitted into the spaces around the cylindrical core and the spherical concrete pressure vessel, and so surrounded the whole core, with only two small spaces for man access for inspection and repair. Bob explained how the various boiler tubes were arranged in groups and how these were fed with water and delivered steam to the turbines. Due to effects of moisture in the core, boiler leaks were not acceptable - but they first occurred in 1972, after just over a year of operation of Wylfa 2. The failure was due to fretting and did not occur on Wylfa 1 which had been built in a less rushed way. The repair led to loss of some tubes which reduced the reactors thermal efficiency. Some three years later Wylfa 1 suffered boiler leaks near the man-access where the temperatures were somewhat higher leading to an erosion-corrosion degradation mechanism. After an intensive period of research the problem was brought under control. Finally a third group of failures, due to on-load corrosion which removed the protective phosphate coating on the tubes, occurred in 1996. This escalated rapidly in 1998, but was solved by restarting phosphate dosing.
which had been stopped in 1994. The effects were again greater in Wylfa 1. The overall effects of boiler leaks were more deleterious on Wylfa 1, which is why Wylfa 2 is the remaining operating reactor. Bob concluded by saying that each problem potentially threatened to shorten drastically the generating life of Wylfa but that none of them did is a testament to an enormous amount of very hard work by many dedicated and clever teams in many locations and by incredible teamwork between those teams.

The operation of nuclear reactors and their decommissioning leads to the production of radioactive waste and spent fuel. Alun Ellis, of Radioactive Waste Management, gave a presentation in which he reviewed the various ways of dealing with different types of radioactive waste. He described the quantities of waste arisings form each Magnox site and gave some insights into the differences between sites due to operational or design aspects. Most of the waste finishes up at Sellafield and is stored there, unless it is low level when it is disposed of at Drigg. The final destination of high and intermediate level waste is geological deep disposal but the site is still undetermined. Alun described the way policy is developing to reach an acceptable resolution of this issue.

Finally the future of the Wylfa site was the subject of presentations from Steven Hall of Hitachi and Jacob Home of Horizon. Horizon plan to operate a Hitachi designed ABWR as Wylfa Newydd and Steven described the basics of the design: there are no BWRs operating in the UK at the moment and the regulators are considering the design through the Generic Design Assessment process. The ABWR is still at about two years from getting regulatory approval. Horizon, as the operator will then need to obtain a licence to construct and operate the reactor. For the project, Jacob said it intends to build two 1350 MWe reactors at the site with operation starting in the first half of the 2020s.

The meeting concluded with a well-deserved vote of thanks to everyone involved in its organisation. Wylfa site director Stuart Law said: “This was an excellent event and the messages from the day were very clear – the Magnox design was very successful. Its concept established a UK industry – some of the innovations involved were world firsts – and over the years the stations have had an excellent safety record. Between them they produced over 1000 TWh of electricity. The closure of Wylfa will be the end of an era.”

Thanks go to Wylfa for providing the venue and lunch which helped to make this event a big success.

Geoff Vaughan is the Chairman of the Nuclear Industry Group

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Nuclear Data Talk
A report on the talk given by Dr Robert Mills, Research Fellow at the National Nuclear Laboratory, at EdF Barnwood, April 2016.

David Weaver and Robert Mills

Dr Mills identified “Nuclear Data” (ND) as “Parameters required to model the nuclear physics of an applied/industrial process to give engineering relevant quantities.” Derived nuclear datasets should meet the following:

- Smallest possible number of parameters that preserve the required physics;
- Simplified, if possible, for easy use;
- Best possible agreement with differential measurements and underlying theory;
- Completeness;
- Self-consistency and agreement with physical constraints;
- Produced in a standard format for easy use;
- Frozen version that can be referenced;
- Validated for use in standard benchmarks.
The principal applications have been: Criticality; Static and transient reactor operation; Reactor accident studies; Neutron transport & shielding; Radiation damage; Spent fuel composition; Fuel cycle calculations; Waste management and Geological disposal. New needs e.g. in proton transport, medical applications and radioactive waste transmutation have broadened these traditional areas. An important component of the data is the uncertainty determination and Dr Mills emphasised the new need for covariances between multiple derived parameters, so that propagated uncertainties on calculated quantities can be determined correctly.

The process of “Evaluation” takes Inputs; all the differential measurements available and relevant physics theory, approximations and physical constraints (conservation of energy, charge etc.). These inputs are then subjected to a data-type specific Process which determines the “Best fit” to the inputs (both measurements & theory). This process must generate complete datasets – i.e. gaps in the data must be filled conserving any physical constraints. This process produces an Output which can then be used by modellers. The Evaluation produces a frozen version of the data in standard format which can then be subjected to testing against, for example, integral benchmarks. The results from testing and application of the output data file will usually lead to a further round of evaluation, perhaps with additional data or revised theory.

Initially individual countries developed their own data and formats; however, efforts have become merged and the principal files today are: Evaluated Nuclear Data File (ENDF) (Americas); JEFF (Europe, Korea), JENDL (Japan), CENDL (China), BROND/ROSFOND (Russia + former Soviet Union states). The Joint Evaluated File (JEF) started in the 1980s; it was renamed around 2000 as closer links were made with the European Fusion File (EFF) to form the Joint Evaluated Fission Fusion file (JEFF). JEFF is a volunteer project i.e. partners need to obtain their own funding for work. Any bona fide engineer or scientist from the OECD Nuclear Energy Agency (NEA) Data Bank countries can attend, present, or contribute data.

The NEA Working Party on International Evaluation Cooperation (WPEC) manages co-operation between ENDF, JENDL, ROSFOND/BROND, JEFF and CENDL and operates in close co-operation with the Nuclear Data Section of the IAEA. It was established to promote the exchange of information on nuclear data evaluations, measurements, nuclear model calculations, validation, and related topics, and to provide a framework for common activities. The working party assesses nuclear data improvement needs and addresses these needs by initiating joint evaluation and/or measurement efforts. For more details or to become involved see https://www.oecd-nea.org/science/wpec/.

EXFOR is an “exchange format” designed to allow transmission of nuclear-measurement data between the Nuclear Reaction Data Centres: IAEA Nuclear Data Section; OECD NEA Data Bank; US National Nuclear Data Center and the Russian Nuclear Data Center, Obninsk. Evaluators and other interested parties can also obtain the data from their local centre. For the UK the local web-site is http://www.oecd-nea.org/janisweb/search/exfor. EXFOR is the main source of data for evaluators. Each entry tries to pull together all relevant documents (journal papers, lab reports, theses, conference papers) to report the final result of a particular work. Dr Mills made a plea to experimentalists: “Please put your numeric data somewhere retrievable (e.g. the appendix of a thesis, an internal report etc.) as reading data from a small 5x5 cm figure in a journal (often log-log!) will never show the accuracy you have worked so hard to achieve!”

He then mentioned three other international activities: (i) the Evaluated Nuclear Structure File ENDSEF, a good source for experimental data to aid decay data evaluations; (ii) the partially EC funded EURATOM H2020 calls - here specific tasks are put out to contract via bids for European consortiums; (iii) IAEA Collaborative Research Projects - IAEA has broader remit that NEA so CRP’s tend to be more general than those in WPEC or individual evaluation projects.
Dr Mills made a series of “Adverts”, including: (i) the Conference on Nuclear Data for Science and technology (ND2016), Sept 2016, Bruges, Belgium [www.nd2016.eu](http://www.nd2016.eu/) and (ii) the newly formed UK Nuclear Data Network, intended to bring industry and academia closer together working on ND, this is funded by STFC and managed by the Universities of Manchester, Surrey and York, and two National Laboratories (NPL and NNL). It started on 1st April 2016 and will run for 4 years.

Validation is an important feature of the development and testing of a data file. Current methods for determining uncertainties on spent fuel inventory calculations rely upon validation against experimental measurements. However, due to the difficulties of such measurements and their costs, the range of validated nuclides, and quantities, is small and the number of measurements limited, thus better uncertainty assessment within calculations can help target such work.

Finally he noted the importance of covariance information. A slide showed the JEFF-3.1.1 file data and a calculation of cumulative yields from independent yields and their uncertainty without the covariance terms (i.e. assuming independent uncertainties). The results show that without the covariance terms many of the cumulative yield uncertainties were over-estimated.

In conclusion, Dr Mills commented that there is still activity on nuclear data, but it is reducing world-wide. There is an international community for nuclear data through NEA, IAEA etc. but he emphasised that the UK must engage if it wishes to use these resources to solve UK issues, or go it alone at much higher cost. The UK has a strong history of work in the nuclear data field and some remaining expertise, but we must act NOW if these are not to become history. The work presented in the talk was funded by EURATOM Framework projects, Sellafield Ltd, the NDA, AMEC FW and NNL Internal R&D.

David Weaver is a member of the NIG committee and Robert Mills is a Research Fellow for Nuclear Data at NNL.

**Small Modular Reactors – the Real Nuclear Renaissance**

A lecture by Professor Juan Matthews of the Dalton Institute, Manchester University, Geoff Vaughan

On 25th May Professor Juan Matthews, a long time nuclear professional, who has worked in the UK Atomic Energy Authority, for the Government’s Trade Bodies and latterly in developing future trends, gave his view on small modular reactors (SMR).

Professor Matthews pointed out that “in the beginning” all reactors were small, Calder Hall was only 60 MWe, but from the 1970s onwards the trend was to large reactors of 1000 MWe or greater. This was driven by economics, but also the grid had developed and could take large generating stations. In other countries, for example India, there is still a call for smaller plants as their grid is fragile. The official definition of “small” is 300 MWe, for plants designed for grid connection, but very small plants 20 MWe or less are being considered for other uses off grid.

After Three Mile Island, the US became interested in smaller reactors, particularly post-2000 to replace coal, but shale gas development has reversed this trend in more recent years. The US saw several advantages of small reactors: the possibility of modularity and factory build being significant. Other advantages were noted, simpler so safer using passive systems, more flexibility on siting and learning by building many units, but to compete with large plants cost was the main issue.

The UK’s interest started in the late 1980’s as it was realised that privatisation would affect investment decisions in large plants: but the dash for gas won. However, interest has perked up and from March 2013 there have been a series of actions with DECC commissioning an in-depth Techno-Economic assessment to which Professor Matthews contributed. Although this has yet to be published, both the November 2105 Government Spending review and the 2016 Budget mentioned SMRs. A £30million competition has been set up this year to look at the possible systems and identify the most promising options.

So what does the UK want? SMRs give the UK a chance to get a stake in the development of new designs – possibly as a partner as is the case for aircraft. There seems to be a market. In the UK, SMRs could be deployed on existing sites where the space is restricted so large
plants would not be feasible. By siting near conurbations, waste heat could be used for district heating schemes which he noted were used in several modern housing developments. In addition, several countries either can’t have a grid due to their size or have fragile grids so can’t build large plants (eg Russia) Professor Matthews also noted that to use more nuclear in the grid is difficult as load following is not easy for large NPP, but SMR could be used by switching on and off. The difficult issue is that there over 70 designs and it’s difficult to predict which will be the winner.

Professor Matthews then went to describe some of the SMRs that were being considered. He pointed out that the main interest at the moment is in Integral PWRS designs which have the steam generators inside the reactor pressure vessel (RPV). These designs have several safety advantages, including: primary pumps are not needed, which also means transition welds are unnecessary; the pressurizer is also in the RPV; the lack of large penetrations of the RPV mean large loss of coolant accidents are not possible; a lower core power density and a larger volume of water; and a larger surface area to power ratio making decay heat removal easier.

Several different designs had been developed and of these the lecturer suggested the designs from Westinghouse (225 MWe) and NuScale (50 MWe) seemed the most promising. The RPV is not significantly smaller than a large PWR; however, there is a significant saving on size as there are no separate pressuriser or steam generators, which allows for a small, tight steel containment. The concept for the NuScale system is that the containment is under a vacuum and several reactors are placed in an underground water pool: should there be an accident, the vacuum can be broken and water will enter and cool the plant.

The reason for building large plants was economics, so how do the costs for SMR stack up? Interestingly, although the SMR are more compact and occupy less land in absolute terms in terms of MW/m² they are comparable. The capital cost of plant is fairly flat above 300 MWe but if construction time can be reduced by developing modular/factory built systems or part systems then there is a potential saving as interest costs on financing are higher during construction. Current SMR construction times, based on modular designs, are predicted to be around 2/2.5 years whereas large plants take 2-3 times longer at best.

This means building a factory however, and this of course means that advantages of cost reduction will only occur as the number of plants built increase. To get to this stage will need tens if not hundreds of plants. Also the modular parts will have to be of a size and weight that can be transported – Professor Matthews noted that Airbus wings of about 60 tonnes were flown from the UK to France, so this was possible. He also noted that advanced manufacturing technology was being researched over a range of techniques and processes which could reduce costs further. These developments were helping the UK to get back into the nuclear manufacturing area.

Overall, Professor Matthews was optimistic that SMR could help to both renew the UK’s role in nuclear developments and contribute to the generation of electricity in the country.

Geoff Vaughan is the Chairman of the NIG.

**Geological Disposal**

**A half-day seminar held at the Birchwood Centre Warrington on 13 July 2016**

**Dale McQueen**

In collaboration with Radioactive Waste Management Ltd and supported by the Nuclear Institute (North West Branch), the IOP NIG organised a seminar to learn about the most current issues associated with radioactive waste disposal from some of the industry’s leading experts. Over 90 delegates attended the seminar at The Centre, Birchwood, Warrington
from across the industry and the country and provided a great networking opportunity for those present!

The seminar was opened by Professor Laurence Williams; an Emeritus Professor of Nuclear Safety and Regulation, Chairman of the Committee of Radioactive Waste Management (CoRWM) and one of the most highly respected individuals within the field of radioactive waste disposal. Laurence spoke about the history of the nuclear industry and the UK’s accumulation of radioactive waste and why deep geological disposal is the internationally recognised best practice for disposal of radioactive waste. He provided the audience with an overview of some of the key legislation and summarised the anticipated forward plan for the UK with regards to the regulatory framework for implementing Geological Disposal in the UK.

The seminar then explored some of the key topics surrounding radioactive waste generation and management. Ed Matthews (Strategy and Technical Portfolio Manager, Sellafield Ltd) followed Laurence Williams’ opening by exploring in a bit more detail the history of the UK nuclear industry and explaining why the Sellafield site hosts a significant proportion of the UK’s nuclear waste inventory. Ed provided a series of video clips that demonstrated the progress being made in decommissioning the legacy facilities at Sellafield and the need for a disposal route for the radioactive waste being remediated.

Our third speaker, Dr Stephen Hepworth (R&D Programme Lead, Sellafield Ltd), provided an interesting insight into some of the innovations and technologies that are being used as part of the decommissioning mission at Sellafield and in dealing, more broadly, with radioactive waste. The audience was able to see video footage of the development and subsequent deployment of an Unmanned Aerial Vehicle (UAV) at Sellafield (where the bulk of the UK’s radioactive waste resides) and the benefits this provides for radiation mapping and decommissioning plant safely and cost effectively. The audience was also provided with a clip of the “lasersnake” demonstration, which illustrated the challenges with dismantling complex pipework in a radioactive environment and the benefits of applying existing technologies to the nuclear industry, all in support of decommissioning our nuclear legacy and, ultimately, disposing of radioactive waste.

Dr Ciara Walsh (Integrated Waste Strategy Manager, Sellafield Ltd) then provided the link between decommissioning and the retrieval of radioactive waste and the ultimate geological disposal of radioactive waste by explaining how the waste generators package the waste for disposal. Ciara explored some of the innovations that have been used on the Sellafield site to simplify the process of generating a robust package for disposal.

The second half of the seminar explored the waste disposal facets of the industry. Paul Skelton (Head of Sellafield Assessments, RWM) provided an overview of the process that waste generators need to adhere to in order to ensure that their waste packages are suitable for disposal. Paul explored some of the key concepts that RWM use as part of its assessment process and stressed the importance of sharing learning across industry and that the disposability assessment process is a ‘live’ process, ensuring that any new knowledge can be incorporated into any assessment (all part of the Radioactive Waste Management Case).

Lucy Bailey (Acting Head of Disposal System Assessment, RWM) provided an overview of the safety case for geological disposal. This provided the audience with an overview of some of the more technical aspects of geological disposal and the generation of a generic safety case. The safety case is necessarily currently generic as the site of the geological disposal
facility is not yet known. However, the key safety functions of geological disposal are known (containment of waste, waste form characteristics, chemical conditioning, mass backfill and geological containment) as well as the safety assurances that can be made from mathematical modelling and using natural analogues (as well as many others).

Lucy discussed the geological disposal system in terms of three key elements – source-term, geological environment and biosphere considerations and gave a brief overview of each. The importance of testing our understanding, using the latest data and information, was stressed throughout.

The closing speech was delivered by Natalyn Ala (GDF Siting Director, RWM Ltd) who spoke of the next steps for geological disposal in the UK. Natalyn gave the audience an overview of the latest developments, the findings from the latest consultation and gave an indication that the next stage of the public consultation was due to be initiated later in 2016/17.

Geological disposal of radioactive waste is as much an emotive topic as it is a scientific one, and through collaboration between Sellafield Ltd, RWM, IOP Nuclear Industry Group and the Nuclear Institute the seminar was able to provide an informed, interesting and accessible discussion for the general public that led to some lively debate. Overall, a successful day and the IOP NIG would like to thank all those involved for their support in helping make the event a success.

Dale MCQueen is a Business Strategy Analyst at Sellafield Ltd and a member of the NIG committee

ANSRI 2016
The NIG part sponsored an event at University College Dublin, on 11-13 May 2016.

The ANSRI workshop aimed to bring together scientists and engineers from different areas of research in physics and industry, to consider the next generation of scintillators for a large range of applications.

The goal of the workshop was to address the shortfalls of current scintillator detectors and to explore possible solutions to these problems. The latest developments in inorganic and glass scintillator technologies were discussed, and the workshop hosted a mixture of invited and contributed talks as well as a poster session.

The workshop covered a range of topics including novel scintillators, characterisation, growth and production, detectors and photosensors. The applications of scintillators addressed included, medical imaging, defence / security, astrophysics, and nuclear / particle physics.

Further details can be found on the ANSRI website http://spacescience.ie/ansri2016/.

COSIRES13
The NIG part sponsored an event at Loughborough, 19-24 June 2016

The 13th COSIRES (Computer Simulation of Radiation Effects in Solids) meeting was held at Loughborough University from 19-24 June 2016. It was sponsored by various Groups of the Institute of Physics (IOP) and also by CCP5 and the International Atomic Energy Agency. The meeting was also held in conjunction with the Second International Workshop on Models and Data for Plasma-Material Interaction in Fusion Devices (MoD-PMI 2016). A conference dinner was held on the Great Central Railway between Loughborough and Leicester in Pullman carriages pulled by a steam train “Witherslack Hall”. Some lucky overseas delegates were able to have a footplate ride.

The meeting was attended by 115 participants from 24 different countries. Many different techniques were applied, from quantum mechanical simulations through to phase field and finite element modelling.

Thanks to sponsorship it was possible to support 36 PhD students with a reduced conference fee and waive the fees for 2 more. The local organising committee and the
international advisory committee also supported 21 PhD students with oral presentations. This is a good international meeting at which PhD students can get their first chance of international exposure and subsequent job offers.

The conference covered a range of topics from particle surface interactions to radiation effects in fusion materials. A highlight of the meeting was an invited talk by Professor Kazuto Arakawa from Shimane University in Japan who showed wonderful TEM images to highlight the dynamics of radiation-produced defects in metals showing good comparison with simulation predictions. Other invited speakers included Barbara Garrison from Penn State University who gave an historical perspective on the early days of sputtering simulations besides her more recent work on the effects of bombarding polymers with ion beams for SIMS applications.

There were many contributed talks concerning fusion applications and an interesting presentation which showed how helium bubbles could grow in tungsten was given by Luis Sanderval, from work carried out at Los Alamos. A novel application with direct links to Chernobyl was a presentation on modelling radiation damage in cement by Andres Saul from CEA.

The full programme of talks can be seen on the conference web site www.cosires2016.co.uk

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## Future Events

The NIG is pleased to announce the next few events which may be of interest to our membership.

**Wednesday 2nd November 2016 ‘Generation IV’ by Richard Stainsby of NNL Venue University of Birmingham**

This event is being organised by the NIG in association with the University of Birmingham Symposium series. Details will be distributed shortly.

**Tuesday 15th November 2016 “Nuclear Security”. The talk will be given jointly by Robert Rodger of NNL (general nuclear security) and Graham Urwin, Security Manager at RWM (cyber security).**

The talks will start at 5.30pm, with refreshments available from 5.00pm. The event will take place on the Harwell campus. Details of the venue to be distributed shortly.

**February 28th “The UK’s Nuclear Future” Dame Sue Ion to talk at Birchwood, Warrington.**

This event is being organised by the NIG. Details of this evening lecture will be released closer to the event.

**May/June 2016: “Update on GDA for UK New Reactor Build” Mike Finnerty, Deputy Chief Inspector at ONR for the New Reactors Programme –Birchwood centre, Warrington.**

This event is being organised by the NIG. Details of this evening lecture will be released closer to the event.
Autumn 2016 “Contribution of Women to the Nuclear Industry” – half/full day event
venue TBD

This event is being organised by the NIG, jointly with the Women in Physics Group. Details of this event will be released closer to the event.

1-3 November 2016, CARM2016 NPL Conference on Applied Radiation Metrology (CARM2016) National Physical Laboratory, Teddington

This event is being organized by NPL. The themes of the conference are:

- Measurement of radioactivity for site characterisation – why it is important and new approaches to on-site and rapid measurements
- Radiation protection and the measurement of airborne radioactivity (incorporating IRMF and ARMUG)
- Nuclear data for the nuclear industry and nuclear medicine

Further details can be found on the CARM2016 website

June 11th-16th 2017 Victoria Warehouse in Manchester European Nuclear Young Generation Forum (ENYGF) from.

This event is being organised by the Nuclear Institute YGN. Held every two years around Europe, the ENYGF is seen as the main opportunity for young nuclear professionals to be heard on a global stage and past events have seen hundreds of young people in attendance. This week-long event is being organised by the UK Nuclear Institute’s Young Generation Network and will feature expert speakers, interactive workshops, technical sessions, site tours and an exhibition as well as extensive networking opportunities through social and cultural events.

The theme of the event is “Innovation in Nuclear: A Rich Heritage and Our Bright Future”; a theme which is befitting of the Manchester location for it was here at the university that early advancements in nuclear physics led to the birth of the nuclear industry as we now know it.

Abstract submissions for the technical sessions (a best poster and best presentation competition will be run) are now being accepted and registration will open on 10th November 2016.

For more information please visit the website http://www.enygf.org/, contact us via mailto:enygf2017@nuclearinst.com or tweet us @ENYGF. You can also subscribe to our monthly mailing list through our website to ensure that you stay up to date with developments.
Items for the next newsletter – Submit an Article

We’d like to hear what you’re doing, what you think of the Nuclear Industry Group, any ideas you may have for networking opportunities or anything else you think would be of interest to the rest of the Group. We plan to publish the next Newsletter in autumn 2017.

Please submit any articles and accompanying photographs or pictures to Heather Beaumont (mailto:heather.beaumont@amecfw.com).

This newsletter is also available on the web and in larger print sizes.

The contents of this newsletter do not necessarily represent the views or policies of the Institute of Physics, except where explicitly stated. In addition the views and opinions stated in this Newsletter do not represent those of the organisations employing the article authors.

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