NUCLEAR ENERGY AND RELATED RESEARCH IN UNIVERSITIES; ACHIEVING THE INTELLECTUAL AND FUNDING FRAMEWORK

A J H Goddard and C R E de Oliveira
T H Huxley School of the Environment, Earth Sciences and Engineering
Imperial College of Science, Technology and Medicine
Prince Consort Road, London SW7 2BP, UK.
a.goddard@ic.ac.uk ;c.oliveira@ic.ac.uk

ABSTRACT

The purpose of this paper is to discuss the research role of universities in the UK, and how this can contribute to nuclear safety competence in industry, to motivating young researchers towards the nuclear industry (and its employment prospects) and to contributing to a wider informed awareness of safety and other issues. We shall not be dealing with undergraduate (first degree) training or with Masters programmes – which will clearly be the main route for industry staff recruitment.

1. INTRODUCTION

How can universities contribute to the maintenance of nuclear safety competence into the 21st century? The University attitude to maintaining nuclear safety competence is naturally shaped by the role that universities are given by government through its central funding arrangements for university infrastructure. The UK government, in its performance measures, takes into account contacts with industry. This provides an incentive. But we shall see that research excellence is the main measure in determining the amount of funding coming from central government to a particular university.

Industry is required to operate safely and profitably – and pressures from shareholders/stakeholders, the safety Regulator and public opinion ensure this. In maintaining safety competence, industry can benefit from the research activities of universities, but needs to accept that universities must operate and compete in a manner consistent with government policy. Thus specialised technical benefits to industry will depend on how universities respond to government direction and how industry influences this. This paper attempts to identify these benefits and explores how industry and universities can best work together.

The independent technical role of university staff is an asset to the Regulator in seeking independent advice and the paper touches on the role and composition of the Nuclear Safety Advisory Committee. International initiatives in post-experience training are also noted.

2. UNIVERSITY RESEARCH ROLE

The United Kingdom government influences national research policy, at the highest level, through the Foresight programme. The Foresight programme began in 1993 and has the aim to identify opportunities in markets and technologies which will enhance the nation's prosperity and quality of life. It is spearheaded by 16 Panels consisting of representatives from industry, government and academia, set up to explore opportunities in different sectors of the economy. Issues that emerge from the Foresight Panels (which publish regular reports) are taken into account by the national Research Councils that allocate additional funds to universities, for specific research projects and which are subject to peer review. The Research Councils judge proposals from individual researchers primarily on the basis of originality but also on the basis of industrial relevance as expressed by these Foresight objectives.

However, the primary funding route is the core infrastructure funding which is received directly from government. For a particular department this will depend on the competitive national Research Assessment Exercise. In this Exercise (the RAE), carried out approximately every four years, each department in a specific technical area competes nationally with all other departments in the same area. The result strongly influences the amount of money received by the university to operate this department. Research excellence, judged on an international basis, again plays primary part. The measures are: the quality of publications; the extent of postgraduate research activity as indicated by the number of PhD research students; evidence of esteem by external funders (eg industry), as indicated by the nature and volume of research income; and evidence of vitality and a strong research culture within the particular department. University staff will thus be motivated to towards industrial technical problems, not only by the prospect of direct research support, but by the influence this will have on their core infrastructure funding.

Industry thus needs to recognise universities primary, government directed, motivation towards international grade research excellence in selected areas, and to seek ways of influencing and benefiting from this through access to front-line innovation and to well-motivated young researchers coming out of PhD training.

We can add at this point that Imperial College, operating the last research reactor in the United Kingdom (the 100kW CONSORT pool-type reactor), has a special interest in maintaining safety competence, but this is not an issue of national significance.

3. INDUSTRY FROM A UNIVERISITY PERSPECTIVE

In the United Kingdom the major part of nuclear electricity generation has been fully privatised. University academics are therefore aware that industry needs to maintain a both a safe and an economic operation. They will be aware of industry’s need to maintain a ‘living’ safety case and to be fully conversant with up-to-date international standards of operation, maintenance, waste management etc. and the need to be able to respond to emergencies. And the need for quality assurance will impose demands both on staff in industry and on those contracted to perform work for the utility, whether industrial consultants is or universities.

It is clearly fallacious to take the view that, because nuclear energy is a relatively mature technology, it should not actively take an interest in front line scientific and engineering research. There are several reasons for this. An awareness of front-line technology is needed to take an economic advantage of the latest developments in software, inspection technology, etc; to ensure that industry staff are equipped to take advantage of these latest developments; to ensure that they are able to match evolving international safety standards; and to ensure that potential recruits in universities are sufficiently motivated towards them. Industry therefore has a strong incentive to ensure that, while universities and their PhD students have an orientation towards international excellence in research, the spin-off applications to industry are rigorously identified and good contacts maintained.

4. BLENDING RESEARCH EXCELLENCE WITH INDUSTRY APPLICATIONS

How can then universities help industry in maintaining its competence, and safe and economic operation? The answer, at least within the United Kingdom, is that universities need to continue to focus on international research excellence, but be indirectly helped in this by industry. And industry needs to ensure that it features in the government's Foresight priorities. Industry can bring about the transfer of technology and knowledge (in both directions) via regular, structured contacts, the placement of contracts to fund applications of basic research to industry's needs. But as noted above, industry needs to recognise that the objectives for universities are set by government and that effecting transfer of technology to various sectors of industry is only one of these objectives.

We have included three examples of how the transfer, to industry, of basic research is being achieved in our research group. Research is conducted into Numerical Methods in Engineering topics of an original, basic nature, but the application of this research is to topics of industrial relevance Examples from nuclear fuel cycle optimisation, from refined calculations of rating distributions in reactor fuel elements and from criticality modelling. The corresponding basic research themes are in optimisation mathematics, self-adaptive numerical modelling, and in multi-phase flow modelling.

(a) Optimisation mathematics

Optimisation mathematics is a fruitful area of research in Engineering Departments, where new techniques such as those involving neural networks are being developed a and where there are a wide range of applications ranging from plant operation to numerical analysis. The example that we have selected is taken from the work performed by a PhD student, (Hmaida, 1999). The diagram shows improvements in the optimisation of PWR core refuelling achieved by using a technique called *Tabu Search* rather than a conventional *Genetic Algorithm* approach.

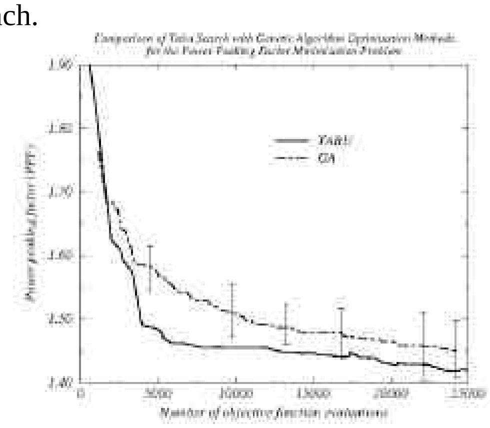
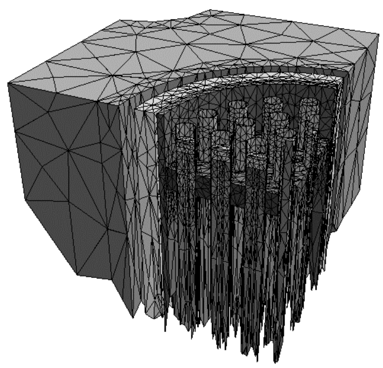


Fig. 1 Comparison of Tabu Search with Genetic Algorithm for optimisation of PWR power peaking factor

(b) *Self-adaptive numerical modelling*

A topic of current international interest is engineering modelling methods that self-adapt, for example in the spatial mesh, to the physics demands of the problem. Such approaches have the potential to yield a desired accuracy with the minimum computational effort and without the unreliability of human intervention. The range of applications are extensive, ranging from structural mechanics to computational fluid dynamics. The accompanying illustration shows an adapted finite amount mesh for a neutron transport calculation within the fuel element of an Advanced Gas Cooled reactor (Umpleby, 1999). The mesh has been adapted (optimised) in relation to the curvature of the thermal neutron flux.



Adapted Finite Element Mesh for AGR – top section

Fig.2 Self-adapted computational mesh at top section of AGR fuel assembly

(c) *Multi-phase flow modelling*

There is continued international interest in the mathematical, physical, and numerical modelling of multi-phase flow - which has applications in the chemical, oil exploration and nuclear industries, for example. We modelled (in collaboration with the French IPSN organisation) rising bursts of radiolytic gas evolution, arising from transient criticality in fissile solutions (Pain, 1999). These methods have been coupled to radiation transport methods. Because such methods, if they are properly benchmarked, are fundamentally based, they may be used to explore and scenarios beyond the range of experiment. The accompanying diagram shows the modelled pressure in dilute plutonium solution (a medium having a combined positive temperature/density coefficient), held in a tank which is being continuously filled.

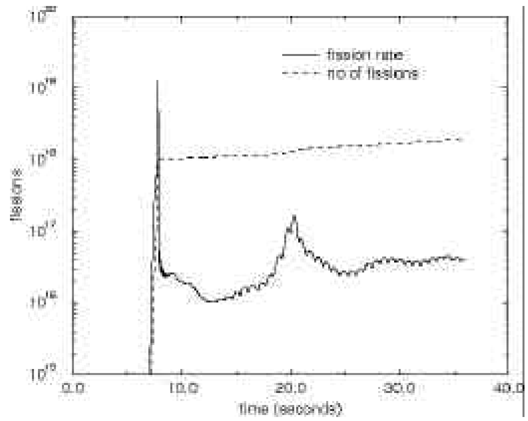


Fig.3 Time evolution of fission rate and no. of fissions for continuously filled drum

Thus, it is possible for universities to undertake research, and PhD research training of young people, to the highest international standards, while becoming familiar with and assisting industry in meeting its targets.

5. PhD RESEARCH TRAINING

Because national Research Council funds are limited, with a high degree of competition, industry funding of a PhD programmes is vital for UK universities. We have indicated above how such young people can become familiar with industry while receiving research training of sufficient originality. The essential message for universities, however, is that the framework of such PhD support needs to be flexible in order to meet industry's realistic requirements. Thus a PhD programme needs to be able to accommodate students who will work wholly in the university; students who will spend substantial periods working with their sponsoring industry, and students who essentially are employees of a particular science-based industry. In the latter case, there need to be research supervisors both in the University and in industry - and of the industry may need to be recognised by the University to have the proper research environment. This is not always possible.

Young people emerging from such PhD programmes should be motivated have their next career placement in the industry. Through their studies they will have fostered the two-way exchange of innovation and of technical issues. It is appropriate here to note the value, to our PhD students, of the post-experience Frederic Joliot/Otto Hahn Summer Schools in Modern Reactor Physics and the Modelling of Complex Systems, which are held annually at Cadarache or Karlsruhe – and whose steering bodies include academics from several European universities.

6. NUSAC

University staff can assist at the interface between the public, government and industry, by offering independent advice. One way in which this is achieved in the United Kingdom is through the Nuclear Safety Advisory Committee which advises the Health and Safety Commission. The Commission oversees the Health and Safety Executive - which embraces several industrial inspectorates (regulators), including the Nuclear Installations Inspectorate. The terms of reference of NUSAC are as follows:

"To advise the Health and Safety Commission and, when appropriate, the Secretary of State, on major issues affecting the safety of nuclear installations including design, siting, operation, maintenance and decommissioning which are referred to it or which it considers require attention. To advise the Health and Safety Commission on the adequacy and balance of its nuclear safety research programme."

While a proportion of the members of NUSAC are appointed to represent, say, Trade Unions, a significant proportion are independent members and among these university staff having relevant experience are well represented. The expertise of these university staff covers topics such as structural mechanics, software reliability, criticality issues and human factors. The papers that are discussed by NUSAC, and the visits to nuclear sites that are undertaken, ensure that the NUSAC members are fully conversant with nuclear safety issues. In turn this spreads familiarity with the technical issues faced by industry into university departments.

Clearly NUSAC is able, where necessary, to express views to government on staffing levels within the nuclear industry and the maintenance of expertise.

7. CONCLUSIONS

We have shown how, with proper mutual understanding, the maintenance of nuclear safety competence can be assisted, while universities continue to follow their essential role laid down by government. Industry will have access to the latest technology and skills to enable it to maintain safety competence at the proper international levels, together with a supply of young people with specialist research training.

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