OECD

Assuring Nuclear Safety Competence into the 21st Century

Workshop Proceedings
Budapest, Hungary
12-14 October 1999

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OECD PROCEEDINGS

ASSURING NUCLEAR SAFETY COMPETENCE INTO THE 21ST CENTURY

Hungarian Atomic Energy Authority
Nuclear Safety Directorate
Budapest, Hungary
12-14 October 1999

NUCLEAR ENERGY AGENCY
ORGANISATION FOR ECONOMIC CO-OPERATION AND DEVELOPMENT

ORGANISATION FOR ECONOMIC CO-OPERATION AND DEVELOPMENT

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NUCLEAR ENERGY AGENCY

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The mission of the NEA is:

- to assist its Member countries in maintaining and further developing, through international co-operation, the scientific, technological and legal bases required for a safe, environmentally friendly and economical use of nuclear energy for peaceful purposes, as well as
- to provide authoritative assessments and to forge common understandings on key issues, as input to government decisions on nuclear energy policy and to broader OECD policy analyses in areas such as energy and sustainable development.

Specific areas of competence of the NEA include safety and regulation of nuclear activities, radioactive waste management, radiological protection, nuclear science, economic and technical analyses of the nuclear fuel cycle, nuclear law and liability, and public information. The NEA Data Bank provides nuclear data and computer program services for participating countries.

In these and related tasks, the NEA works in close collaboration with the International Atomic Energy Agency in Vienna, with which it has a Co-operation Agreement, as well as with other international organisations in the nuclear field.

FOREWORD

In its 1998 report on new future regulatory challenges, the NEA Committee on Nuclear Regulatory Activities (CNRA) has identified the human element as one of the most critical aspects of maintaining regulatory effectiveness, efficiency and quality of work. There is a need to preserve among the staff a collective knowledge in all relevant technical disciplines with sufficient depth to permit adequate independent assessment of safety issues.

Quality organisations require well educated, well trained and well motivated staff. In some countries, national R&D programmes are being reduced to such a point that forming an independent regulatory position might be in jeopardy. If a significant problem occurred over the next ten years, there might not be sufficient knowledge and capability to deal with it in a timely manner if the current trend continues.

Based on these concerns CNRA recommended that a workshop should be organised in 1999 to consider the most efficient approach to recruiting, training and retaining safety staff, and preserving a critical mass of knowledge, both within industry and regulatory bodies.

The Workshop on Assuring Nuclear Safety Competence into the 21st Century was held from 12th to 14th October 1999 in Budapest, Hungary, under the sponsorship of the CNRA. It was organised in collaboration with the Hungarian Atomic Energy Authority.

The meeting was held as a workshop, that is, contributions, to the papers or the discussions, were welcome, and encouraged, from all participants. The objective was to produce specific recommendations. The first part of the meeting was restricted to invited papers which provided the basic data from which options could be considered to establish the recommendations. The scope of the meeting included all aspects of maintaining competence across the nuclear industry as a whole including regulators, utilities and technical support organisations. The aim was to use existing information to profile the situation and to look ahead to the future and identify methods of ensuring that safety is not compromised.

The overall aim of the meeting was to increase the awareness amongst Member countries that failure to maintain nuclear competence is a long-term safety issue. As part of this aim the specific objectives were:

- to exchange information on maturity of nuclear competencies across Member countries and establish current good practice;
- to identify methods of maintaining competencies across all sectors of the industry;
- to develop clear recommendations which provide solutions for the short term and build for the future.

The General Chairman of the Workshop was Mr. Steve Griffiths (Nuclear Safety Directorate, HSE, UK). He was assisted by an Organising Committee composed of:

- Dr. Thomas H. Isaacs (LLNL, USA).
- Dr. Hartmut Klonk (BfS, Germany).
- Dr. Klaus Kollath (GRS, Germany).
- Mr. Géza Macsuga (HAEA, Hungary).
- Dr. Lasse Reiman (STUK, Finland).
- Mr. Manuel Rodriguez (CSN, Spain).
- Mr. Jacques Royen (OECD/NEA).

The role of the Organising Committee was to select invited papers, evaluate the abstracts of papers submitted to the Workshop, organise the Sessions and draw the final Programme, appoint Session Chairmen, etc. The Organising Committee also wrote the Summary and Conclusions of the meeting, and recommendations to the CNRA.

Acknowledgements

We would like to express our thanks to the Organising Committee, the Session Chairmen and all those who contributed to the success of the Workshop by presenting their work and taking an active part in the discussions. Our gratitude goes to the Hungarian Atomic Energy Authority for hosting the meeting and for their kind hospitality. Special thanks are due to Ms. Teréz Orban for taking care of the local arrangements as well as to Miss Anastasia Slojneva for their dedication in preparing and editing these proceedings. The NEA also wishes to express its gratitude to the Government of Japan for facilitating the production of this report.

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EXECUTIVE SUMMARY

A Workshop took place in Budapest between 12 and 14 October 1999 to consider issues concerning assuring nuclear safety competence into 21st century. This was in response to recommendations from CNRA. A number of invited papers were presented along with presentations from Member countries. Whilst there were country differences and perspectives the problems were recognised, particularly the long-term strategic nature of the issues. Action is needed now due to the time lag to restore competence losses. CNRA are invited to highlight the issues to OECD and consider what actions it can take in response to the recommendations made in this report. Specific attention is drawn to:

- The need for a long-term view and planning.
- Preservation of core subjects.
- The Young Generation Network.
- Encourage development of the IAEA documents on regulatory competencies.
- Knowledge capture and advancement.

SUMMARY AND CONCLUSIONS
(Organising Committee Report)

1. Introduction

1.1 Purpose of workshop

In its report on new future regulatory challenges the Committee on Nuclear Regulatory Activities (CNRA) identified the human element "*as one of the most critical aspects of maintaining regulatory effectiveness, efficiency and quality of work.*" There is a need to preserve among the staff collective knowledge in all relevant technical disciplines with sufficient depth to permit adequate independent assessment of safety issues.

There was consensus that

"*Quality organisations require well educated, well-trained and well motivated staff. In some countries, national R&D programmes are being reduced to such a point that forming an independent regulatory position might be in jeopardy. If a significant problem occurred over the next ten years, there might not be sufficient knowledge and capability to deal with it in a timely manner if the current trend continues*".

Based on these concerns CNRA recommended that a workshop should be organised in 1999 to consider the most efficient approach to recruiting, training and retaining safety staff, and preserving a critical mass of knowledge, both within industry and regulatory bodies. These are issues that are of concern not only as part of the wider nuclear industry but also for governments in maintaining an infrastructure to assure safety into the future. Hence it was of particular concern that the common issues between industry and regulator were established.

1.2 Location of workshop and participants

The Workshop was held in Budapest from 12 to 14 October 1999; it was organised in collaboration with the Hungarian Atomic Energy Authority. There were twenty-eight participants, representing organisations in Belgium, Canada, Finland, Germany, Hungary, the Republic of Korea, Mexico, the Netherlands, Slovenia, Spain, Sweden, the United Kingdom and the United States, as well as the International Atomic Energy Agency (IAEA) and the OECD/NEA.

1.3 Reasons for concerns

Irrespective of current views on the future of a nuclear power programme across OECD Member countries there are safety concerns for the future. These arise from the long term ability to preserve safety competence within the industry and the regulator, in particular because the number of enrolments in the fields of nuclear science and engineering are decreasing rapidly in most universities and engineering schools. In addressing this issue the workshop identified three reasons why this was appropriate:

- nuclear power programmes are in place and have to be safely managed;
- nuclear power is international, and events in other countries impact world-wide;
- reasonable options for the future have to be kept open.

Whether there is a strong development of nuclear power into the future or it is terminated there is still a need to maintain competence now and into the future. The nature of these competencies may change but the basic principle of safety remains. This has a further impact on the regulator in terms of the competencies required to regulate. In order to maintain publicly acceptable standards of safety, governments cannot avoid their responsibility. Their responsibility influences the energy markets and hence the industry. The situation is also strongly influenced by the political will, determination and desire to establish an independent effective and competent regulator and an education system which allows for the development of technically qualified talent into the future. Furthermore there is a need to maintain and develop appropriate safety research as this can also provide the catalyst for dynamic and attractive education programmes and co-operation between industry and education.

The nuclear industry is considered, in many countries, as mature and the nuclear safety competence is predominantly vested in the same age group. The age distribution for regulators is over 40 in most countries. In countries with active programmes this age is slightly lower, and in those in decline the situation is worse. The time is rapidly approaching when this group will be retiring, over a period of a few years (this phenomenon was described at the Workshop by the analogy of “the rabbit in the snake”). The situation is similar in the nuclear industry. Doing nothing is not an acceptable option as there is unwavering demand for a high degree of nuclear safety competence for at least one more generation even if nuclear power was terminated immediately. To address the safety implications there will be a need for:

- competence, should there be extensions to present nuclear programmes;
- maintenance of a living safety case;
- safety of operating installations;
- ensuring safe decommissioning;
- safe spent fuel and radioactive waste management.

Programmes to initiate knowledge transfer, suitable research and relevant competence renovation must be started as early as possible or the position will not be able to be recovered.

2. Review of workshop discussions and outcomes

2.1 Workshop format

The number of people attending the Workshop was somewhat smaller than expected. However, this facilitated very open discussions and development of proposals. There was active participation from all experts present. The positions in each country and how the issues impacted on the necessary competencies were established. Ultimately there was significant agreement over the principal issues and ways in which these could be addressed. The key areas identified were:

- no new nuclear plant being built in the majority of countries;
- lack of vitality in research;
- the nuclear industry is considered to be unattractive by new entrants;
- ageing workforce.

These areas will be expanded upon in this report.

2.2 Summary of presentations

The papers presented are set out in the Workshop agenda and the Session Chairmen have produced a summary of the main points and common threads presented during each session.

2.2.1 Overview of position based on presentations

The status of nuclear programmes varies across countries. This leads to differences in perception of the issue. Countries still developing their nuclear programmes such as France, Japan and Korea, and, for different reasons, Central and Eastern European countries, have less difficulty with recruitment to regulatory bodies and the industry. The fact that government confidence in nuclear power is strong leads to a better perception amongst the public, which facilitates the ability to preserve competence. There are still calls for greater efficiency, which can also impact on the regulator. At the other end of the scale there are countries where nuclear programmes are coming to an end in the next few years with no prospect of extension. They have an increasing problem in maintaining competence. These positions represent the extremes of the current situation but show how different national attitudes and policies towards nuclear development will significantly influence the perspective of the problem.

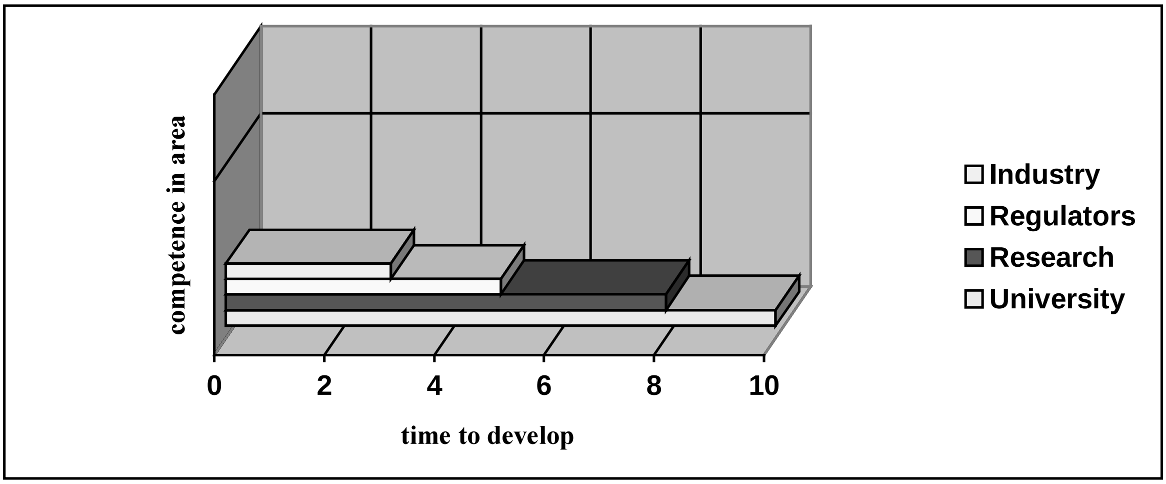
Political factors play an important part, as do public perceptions and the extent of opposition from pressure groups. This impacts on perceptions of young people, though again this varies greatly from country to country.

A significant political component is the desire in some areas for entry to the European Union (EU), which is giving rise to an increase in the requirement to demonstrate achievement of safety standards. In contrast, the break up of the former Soviet Union is giving rise to a different type of safety pressure. Technological support is now becoming more limited and where it is available is provided on the basis of payment from central funds rather than co-operation. This is also impacting on the availability of centralised research facilities.

Some new areas of research are opening up and research is still being maintained in areas such as material science and corrosion. However the traditional areas of research in nuclear fields such as reactor physics are declining. This is also true for several areas of safety research: large thermal-hydraulic facilities are being shut down, severe accident research programmes are reduced or cut. These factors have a significant immediate impact on universities and education and on national laboratories. If the teaching and research facilities cannot be maintained then educational programmes will gradually close. Similarly, as people retire, the competence available to operate university-linked research facilities disappears. Both these factors have a significant impact on the ability to transfer knowledge to future generations.

The factors discussed above are intimately linked. Teaching and research is required in order to produce the right people plus training within the industry and availability of jobs. There is also the need to regenerate lost academic teaching capability. Given the ageing workforce profile there is the danger of competence being lost. Once lost there will be a substantial time lag before recovery of a specific level of competence is achieved. The time to recovery will vary. Figure 1 provides a conceptual illustration of the time to recovery arising out of the Workshop deliberations. Industry has more chance of recovering quickly, as it may be able to recruit from the labour market, however in academia the time scales are much longer.

Figure 1. **Time to develop competence in particular areas**



Deregulation of the energy industry and liberalisation of the electricity market (often also called deregulation) are having a significant impact in some countries and will greatly add to the pressures to reduce manning. This may affect other countries in the future, adding to problems in human resource strategies needed to accommodate the move towards low staff numbers per power unit. It is therefore important to recognise each country specifics when considering the outputs from the discussions held at the Workshop.

Some companies are claiming that electricity market liberalisation gives rise to better standards of safety. This is a premise that is open to challenge and will be a new challenge for the regulator in the future. Paradoxically, preliminary signs show that electricity market deregulation may require a stronger and more effective nuclear regulator (e.g., regulators need to say what is safe in terms of staffing for the long term).

3. Trends

A range of information was presented at the Workshop and even though the country differences have to be recognised, trends could still be identified.

3.1 Academic

Representatives from the nuclear education field presented information, which demonstrated a trend of undergraduate programmes declining in most countries; nuclear departments have been merged or eliminated. University teaching programmes have been broadened, masking the impact of the reduction in student numbers. The OECD/NEA Nuclear Education Study and recent American studies provide the best reference in raw data terms. As programmes close there is less research support available to the industry, which further reduces the potential for attracting students and funding. Additionally, educators are ageing and, as they retire, further pressures are placed on availability of teaching courses and research programmes. On the positive side, whilst there is an increasing lack of interest in nuclear study, there is still a good job market for numerate and technically qualified graduates in other fields. In addition a number of countries have recognised that there is a need to be proactive. In some cases, support for universities is in place to try and maintain key competencies, there are initiatives to look at human resource plans and better targeting of competence requirements.

3.2 Future power programmes

The choices for future power programmes, and indeed existing programmes, depend on economic situation and status of available natural resources, and political considerations. There is an active lobby by anti-nuclear groups but there appears to be an increasing awareness of CO_2 issues post-Kyoto. This provides both a threat and an opportunity. Some green groups are becoming far more sophisticated and use international pressure groups to distribute the message. Regulators also need to become more sophisticated – this is a new skill, and perhaps more aware of international interactions and international collaboration.

3.3 Privatisation

Privatisation is happening more and more as the large state-run monopolies are broken up. This trend was recognised in the CNRA report. A further effect is how this is changing the nature of the operator. Their obligations are wider and they need to be confident, convinced and competent about their responsibilities and duties (there is an important role to be played by safety culture). There is a need for them to act as intelligent customers and ensure that they have the right mix of skills needed for both today’s technology and for that of the future.

The trend of open competition in the electricity supply market is increasing. This affects different countries in different ways and is again related to the status of nuclear power programmes.

3.4 New challenges

There are now new technological and intellectual challenges that are becoming attractive areas for work. The dramatic change in the nuclear weapons programmes has reinforced this trend in the concerned countries. Whilst these challenges tend to be short-term projects, they do provide a feed of new recruitment with the opportunity for knowledge transfer and refreshment of present staff not only in terms of the age profile but also in motivation and passing on of knowledge.

Life extension is one of the aspects a number of operators world-wide are looking at more and more, particularly where there is no new construction in prospect. There are a range of economic and political reasons in each country for this trend. It is causing increased effort on living safety cases and relicensing plus the requirement for research capability to examine ageing issues. These aspects will require resources into the future.

Increasing numbers of plants will move into the decommissioning phase, shifting effort onto the decommissioning activities, long-term storage, waste disposal, etc. This will require research and people to man decommissioning programmes. There will be a consequent impact on regulator and utility. This is a challenge and an opportunity to capture public support and send out positive messages if these activities can be managed properly.

A number of countries can be considered as exporters of design and expertise, however as they are not any longer designing new plants the expertise could disappear while their indirect responsibility – or, at least, their direct interest – in maintaining or improving safety in importing countries will remain. Purchasers of existing technologies may have to become self-sufficient or buy services. The distinction between exporting and importing countries is becoming blurred.

3.5 Nuclear research

Although there is concern about the decreasing level of nuclear safety research resources, there is a continuing need for safety research, for several reasons:

- there are residual concerns (although the range of uncertainties is limited); there is potential for further improvement;
- one needs to be able to address emerging safety issues, and to anticipate problems of potential significance;
- safety research contributes to establishing the independence of the regulator;
- safety research attracts the most brilliant students and experts, and so contributes strongly to the maintenance of nuclear safety competence.

3.6 Co-operation

Increasing international co-operation and globalisation at all levels is occurring. There is international liaison by plant operators (INPO, WANO). Regulators are co-operating more and more. Problems are global but mechanisms for solutions are probably in place.

3.7 Use of the legal system

There is an increasing trend to look to the courts to settle issues. This is happening at national levels and between the regulator and the industry. Technical experts are being challenged more and more and there is an increasing distrust of technical experts. This is leading to the need for a range of new softer management skills for the regulator and the industry. This is exacerbated by the decreasing numbers of technical experts available.

3.8 Economics

Increased liberalisation and pressure to cut costs are giving rise to higher efficiencies in plants such as extended operating cycles or reduced outage times. This could change the nature of the regulatory role.

3.9 Wider challenges

Economics is not just the only challenge – increasingly there is concern over proliferation of nuclear weapons (this could influence the future of reprocessing), over significant climate changes due to the burning of fossil fuels, and over sustainable development constraints. Security of supply is another important consideration as far as energy is concerned.

4. Short term and long term challenges

Arising from the discussions some short term and long term challenges emerged. Some of them have been examined further in relation to the good practice that was presented and summarised as recommendations. For completeness the challenges identified are:

- Adapt to the current trends.
- To find the human potential to deal with current safety case requirements now and draw together the useful historical information.
- How to tap into the experience of staff before and after their retirement – retention of knowledge.
- Transfer of knowledge between generations.
- Document the design-related information that is available and the reasoning that underpins it.
- Establish a methodology to institute a corporate memory. Bring experts together to capture knowledge. Take full advantage of the possibilities of on-the-job training.
- Debriefing of people who have the knowledge e.g. core design.
- Try to change the attitudes and climate amongst the young and rest of population. Project a more positive and more dynamic image of the nuclear power industry: make it a “winner” again.
- Identify the core of nuclear expertise that is actually required – if you were to stop nuclear power now, what would render us unsafe if lost – (the view was that this was not just reactor physics, although it was recognised that few skills are solely applicable to nuclear).
- How to use new and important challenges that are emerging as magnet for new work and allow availability of staff for knowledge transfer. These new, important and motivating challenges – including the development of new concepts and designs – are also the best way to attract the best and brightest young students and experts.
- How to be able to provide the infrastructure to support re-creation of the technology.

- How to anticipate the needs of the industry 10 to 20 years ahead. Contrary to training, education requires long lead times. If the educational system is lost, it takes a long time to rebuild. In some cases, decisions regarding the needs and capabilities of the year 2010 need to be taken now.
- How to preserve the educators and instructors and provide for their own succession.
- Centres of excellence, to maintain and develop expertise and train newcomers to the field, e.g. to provide high level postgraduate training in reactor physics and attract top class students; this concept has been advocated in different contexts, including industrial ones – however much research is needed to keep the trainers going and which steps are needed to regenerate the trainers?

5. Recommendations

5.*1* *Overview*

As discussed earlier, common threads and themes emerged along with some evidence of measures being taken. It was clear that there were aspects that were within the remit of people who attended the Workshop. They had identified the issues and had the opportunity to develop links to other groups or within their own country to try and promote good practice. Bodies such as IAEA already had mechanisms that could also be used. Furthermore, there was a need for wider recognition of the problems and a forum to support the initiatives identified. It is in this area where OECD/NEA have an influence. There are therefore aspects, which CNRA can develop and promote plus lending their support. In this way there is the opportunity to influence the key groups within each country.

The general recommendations have therefore been broken down into groups to reflect this view. The first group concerns recommendations that Workshop participants may be able to take forward or influence CNRA representatives. The second group is targeted more at CNRA as a body. The aspect that needs specific consideration by CNRA is set out in bold.

5.2 *Workshop attendees*

What is it that the Workshop can do, in terms of recommendations to CNRA, to address the challenges?

Several presentations outline work concerning competence frameworks (Canada, Finland and IAEA): these can apply to those within industry and to regulators. **This work needs to be encouraged and drawn together**.

Currently there is a range of international collaboration activities. Better use could be made of exchanges and pooling of staff, fellowships support for joint facilities, pooling of facilities or creation of joint projects, etc. International operator and regulator organisations could investigate and promote pooling of facilities. The Committee on the Safety of Nuclear Installations (CSNI) has initiated programmes to preserve key safety research facilities, programmes and capabilities through international collaboration.

There is also a range of national collaboration activities, e.g. co-operation between universities to provide optimal undergraduate and postgraduate programmes. In Belgium, universities have created a common postgraduate degree in nuclear engineering by combining their education activities into a national network. It has been proposed to extend this scheme to a broader European context.

Regulators need to involve themselves more in the ways in which training is being provided – from university level right the way through to employment. Also examine how industry actually does this, and how plans are made for the future (up to 5 or 10 years: regulators have to get involved in the totality of the “snake”). There is a role for regulators in being proactive. Regulators should also provide for their own continued training. Country examples are available where human resource plans have been developed. **The methodology and approaches can be shared irrespective of the often fundamental problem of availability of staff**.

Operators have a responsibility for the “front end” costs of the training of their own staff, and to some extent of their contractors also. Development of fellowships and co-operation in centres of excellence should be encouraged. **It should not be forgotten, however, that industry focuses on the short term; strategic long-term considerations are the task of governments.**

The responsibility for ensuring competence rests with different bodies. As part of this there is also the responsibility for the provision of adequate training facilities. In some countries, it is the regulator, whereas in others it is the government. This responsibility needs to be understood and clarified. In any case, universities need support from industry, technical support organisations and regulatory bodies (governments), in the form of lecturers, research possibilities, financial assistance, temporary employment, recruitment.

The Swedish Centre of Nuclear Technology is an initiative which found support. It operates with limited funding and manning but is an initiative that could be expanded. It has some features, which parallel the BNFL industry based initiative to maintain radiochemistry competence.

The ENS Young Generation Network, in a number of European countries, is an established and an important and promising network. The paper presented by the YGN at the Workshop set out cogent arguments and suggestions. This paper should be examined and a mechanism established to try and utilise the talent available within the network members. They should also be asked for ideas and suggestions for their recommendations for this topic. National nuclear societies should organise active and substantial programmes for the YGN, give them specific missions and responsibilities.

Young employees should be given responsibilities as soon as possible, in order to speed up the build-up of experience, to make work more interesting and meaningful, and to increase motivation and work satisfaction.

There is co-operation between centres of expertise. Modern communications technology could enhance these linkages and perhaps enable new areas of technology transfer to be established. Use of computer-based conferencing and Internet facilities to utilise some of the sophisticated computer based equipment within the nuclear industry could help to create interest. This is an emerging area not fully covered at this Workshop but could be an issue for the Workshop participants to identify with a view to a specific more detailed workshop.

There is a need to increase co-operation through bilateral collaborations. The Paks NPP maintenance training facilities are unique and appear very sophisticated. There is an opportunity to establish a centre of expertise in VVER technology which could be utilised extensively in the field of training and skill transfer. The facilities could be used commercially.

The participants from the educational field had very positive feedback concerning the Frédéric Joliot/Otto Hahn Summer School in Reactor Physics (held alternatively at Cadarache, France and Karlsruhe, Germany). There is scope for this to be extended and adapted.

One of the most challenging issues is how to reach schools and young people. Attracting young students to nuclear science and technology should start before they choose an education or career path. Programmes are in place in some countries; they need to be investigated further. **This is one area that the Young Generation Network could help significantly**.

There are a number of people and groups throughout the world who have significant knowledge. Furthermore modern technology facilitates easy contact. There is scope for the development of mentoring schemes across countries. Systems operate within countries and within some companies. There is scope for extension of this principle. **A framework for developing such an approach needs to be established**.

5.3 Recommendations to CNRA

General recommendations for CNRA; areas which members can influence but which may be outside their direct control

A number of the areas, which have been identified touch on national policies. Special pleading for the nuclear industry and its problems is not the objective. However there has to be recognition of the issues and willingness for them to be taken seriously. It is in this area that CNRA can help. The specific areas relevant to CNRA are set out below.

A long-term strategic view must be taken. In view of the long term nature of nuclear safety, programmes to ensure the supply of staff with the necessary competencies must look ten years ahead and transcend short-term economic views. Investment in people has similar time scale considerations to those of facility lifetimes. The issue of future training needs to be taken seriously and has to be addressed, as it will not go away. This recommendation is applicable to regulators and utilities.

International collaboration can help but programmes need to be developed and supported.

There is no substitute for government to support the safety aspects, in particular some aspects of safety research. If nuclear competence is to be kept alive then there have to be areas of research and support for research, otherwise it is not possible to maintain facilities and a supply of staff with specialist nuclear physics and engineering skills into the future. Once gone it will not be replaced. **Those disciplines peculiar to the nuclear industry need to be identified and kept alive**.

Regulators need to consider the issues of staff resourcing, training and behaviour as part of their regulatory function. Competence is not just a matter of knowledge but also behaviour.

Volume and quality of resources are important, but knowledge is of no use unless available in the right place at the right time and exercised in the right way.

Interchange of staff between regulatory bodies is recommended. Peer reviews of regulatory bodies are encouraged.

Job task analysis to draw up competence profiles now is needed. From this, a competence gap analysis both for the present and into the future should be undertaken with the commitment to review regularly.

A systematic approach to capturing knowledge is needed. The systems introduced in USA (videotaped interviews, etc.) for capturing knowledge from the decline of the nuclear weapons programmes at the end of the cold war is a useful model which could be developed.

Use needs to be made of new technological opportunities to appeal to young engineers - example of spin-off from weapons programme in US. This is a way of preserving the classical technologies and preserve access to a broader community of young people.

Identify a core of subjects and ring fence to help preserve them. There is still a need for updating and incorporating old codes and methods into new technologies and computer science.

Develop a network of mentors and co-ordinate with the Young Generation Network and beyond. Give the YGN information on appropriate mentors in each specialist field as a way of starting to develop such a network.

Work has been done by IAEA on competencies for regulators. Other countries have developed their own profiles which will help to update the IAEA documents. **This work needs to be sponsored and promulgated amongst Member countries. As a matter of priority**.

6. Specification of further work on assuring future nuclear safety competence

6.1 Introduction

The Workshop reviewed the issues that had been identified and provided information on work in hand along with some recommendations and possible ways ahead, summarised above. The attendees could take up some of the work identified but a more co-ordinated approach from a recognised international body is preferable in order that the recommendations can be developed into specific actions. To assist in developing a co-ordinated approach, the Workshop output has been re-examined to draw out the key issues into a specification of further work. This specification is more targeted and aimed at being developed into a programme of work with actions.

6.2 Competence framework

One of the fundamental issues is to identifying the competencies you actually require. This provides a baseline for assessment of current adequacy and investigation of future needs. IAEA undertook some work a few years ago and developed a competence framework for regulators. Whilst this was aimed at establishing a baseline of good practice it represents a sound starting point. This work is due to be updated and effort is required. AECB in Canada, and STUK, VTT and TVO in Finland, have also done work in this field and developed a framework for their organisation.

Actions

1. Undertake an examination of the competence frameworks developed and published by IAEA, AECB and Finnish organisations.

2. Examine other recent international use of competence frameworks to assist in future development of the IAEA baseline documents.

3. Initiate a review of Member country experience with competence frameworks to establish whether a revised IAEA document represents current best practice.

4. Investigate the feasibility of carrying out job and task analyses for regulators and operators to provide some generic competence profiles.

5. Establish a strategy for updating and developing the competence framework.

6. Based on the revised competence framework identify the core competencies required currently.

7. Identify the core training needs and availability of training facilities with the aim of identifying any gaps.

8. Identify the core nuclear competence requirements and investigate approaches to preserving the competence.

6.3 Encourage co-operation

Several presenters mentioned the need for co-operation across education and research facilities to support for interchange of staff and pooling of resources. This is a very wide topic, which all will support but is difficult to translate into defined actions. The key task is to clarify a few defined areas for co-operation and identify future actions.

Actions

1. Establish the extent of co-operation schemes in use within Member countries.

2. Examine graduate and postgraduate training arrangements that support the core competencies and identify areas suitable for further development of co-operation programmes.

3. Examine the Swedish Centre for Nuclear Technology and the BNFL initiative to support radiochemistry and identify the key features.

4. Identify methods whereby either information on the approaches could be transferred or further centres established either on a national or international basis.

5. Examine the possibility of more extensive use of training facilities such as those at Paks to establish centres of excellence, which are accessible within a region.

6.4 Young Generation Network

The ENS Young Generation Network is an active organisation who is keen to provide assistance. As they already have a network established they could be used to develop contacts further. Further use of such a network will help to underpin actions in other areas such as encourage co-operation.

Actions

1. Establish a forum for improved contact with the Young Generation Network.

2. Utilise the Young Generation Network to develop an action plan for effective communication with schools and universities concerning science and technology.

3. Review the Young Generation Network paper presented at the Workshop and identify the key areas in which they could provide assistance.

6.5 Mentoring

Nuclear expertise is ageing and there is a need pass on knowledge. Modern communication techniques can assist. In particular the growth of world-wide web and e-mail has enabled contacts to be maintained across countries. There is scope for utilising this technology to provide for dissemination of knowledge. The key task is to develop an approach.

Actions

1. Develop the specification and requirements for a mentoring scheme for young engineers.

2. Examine methods of using modern communication techniques.

3. Establish likely organisations that would facilitate and support such an approach.

4. Establish a small group of people prepared to help in a pilot exercise.

6.6 Need for a strategic view

The Workshop identified the clear need for a long-term strategic view to be taken. The difficulty with any actions is identifying the group who would be responsible. CNRA can provide significant influence and through NEA provide a lobby group. The individual regulators can push the need for such a long-term approach within their own organisations and those they regulate.

Actions

1. CNRA to commission a more detailed study to pull together information from recent studies. The objective being to establish the elements of a long-term strategic plan which could be utilised by members.

2. Use the plan developed above as a tool to provide influence internationally.

3. Identify any additional short-term actions based on the strategic plan.

OPENING ADDRESSES

OPENING ADDRESS

L. Vöröss
Deputy Director General, HAEA

Good morning, Ladies and Gentlemen,

It is a great pleasure for me to welcome you all to the Headquarters of the Hungarian Atomic Energy Authority. My name is Lajos Vöröss, I am the Deputy Director General of the HAEA and the Head of the Nuclear Safety Directorate which is the nuclear safety regulator of first instance in Hungary.

This Workshop deals with a very important subject for the time being, namely, how to assure nuclear safety competence into the next century. This is one of the most important future regulatory challenges as it has been indicated also in the OECD-NEA Study issued recently on them.

Since there are very few new nuclear power plants under construction and design nowadays in the world, a certain lack of interest of the young generation has been observed for the nuclear science worldwide. However, expertise will be needed also in the future not only to operate the existing nuclear power plants but also to manage their life extension and their decommissioning as well. The research facilities seem to be in trouble, too: their number is decreasing and less and less financial resources have been available to sponsor R&D work using them.

Ageing of both facilities and manpower needs intervention of all responsible persons to cope with this issue. I am convinced that this Workshop will successfully contribute to give answers to this challenge and will raise ideas what tools should be used to solve the problems connected with it.

We in the HAEA are happy to host this important Workshop of the OECD-NEA and I am, personally honoured to address you these opening remarks and to chair the introductory session. I am especially looking forward to take part in the final session where we will summarise the results and will make recommendations for the CNRA of the NEA.

Originally we have expected a little more participants, however, I think that the size of this meeting is ideal to an open and fruitful discussion. I do hope that the participants will have also the opportunity to visit the sights of Budapest and to enjoy the Hungarian cuisine as well.

Finally, I would like to wish you all a successful meeting and a pleasant stay in Hungary.

OPENING ADDRESS

J.S. Griffiths
General Chairman of the Workshop

Good morning ladies and gentlemen. Firstly I would like to thank you for coming. The workshop concerns a very wide ranging issue that affects regulators and industry alike. Whilst the CNRA report on future nuclear regulatory challenges appears to focus on the regulator, the concerns are equally applicable to operators. Also because of the range of stakeholders in the industry their interest also have to be addressed. There will be country differences but all face some or all of the challenges. I hope that even though we are a small group we will be able to share experiences but more importantly by the end of the workshop have identified, good practices and possible action plans that Jacques and I can be take back to CNRA. These plans will only be as effective as the work you put in here and in terms of your use of networks to help lobby and implement changes or programmes.

I would however like to spend a few minutes to set the scene. The initiator of this workshop was the CNRA report on future nuclear regulatory challenges which recognised the human impact of the technical, political and socio-economic challenges and the threat to the regulatory system. As a regulator I have been comfortable for a number of years with the concept of technical changes. These have tended to be incremental rather than radical as no major system or technological revolutions have been introduced. Also the technical changes tend to have a finite timescale with project milestones. Additionally I am comfortable with changes in thinking about safety regulation. In the UK these have also tended to be incremental or in response to particular safety studies. Such changes have tended to develop from the corporate memory of the individuals within the regulator, the utility and the research or educational community. However if I stand back and put myself in the position of unfamiliarity with the concept of nuclear power regulation where I had had no training and no technical background, such a concept would represent an enormous shift in my understanding. I would not have the corporate memory or experience and many of the ideas could be outside my knowledge and understanding.

The nature of business has changed dramatically. Energy companies are now more than country based and some have global ambitions. This has meant that their organisational arrangements have changed and will continue to change. This represents a significant change for the regulator in their understanding and also in the aspects of safety management arrangements. This raises the question of whether the main challenge for the future is the issues of human performance, organisational management of safety and safety culture rather than technical changes. These are more difficult to think of in engineering terms and do not have the clear technical milestones that we are currently familiar with.

One of my colleagues who specialises in the area of human safety performance and safety culture presented a paper on organisational change in which he set out a number of factors that regulators would look for with respect to demonstration of management of change. The particular aspects concerning human issues are:

- the need to ensure that appropriate competencies are retained within the organisation (or are demonstrably accessible by it) to deal with current and future safety-related operational, technical and organisational needs;
- the need to ensure that sufficient resource is available to deal with current and future safety-related operational, technical and organisational needs;
- identified interrelationships between safety activities: for example, a proposal to re-deploy, or employ fewer, maintenance foremen might affect the training of maintenance staff as well as the control and supervision of maintenance activities;
- demonstrated that there remains a critical mass to sustain safety-related technical support functions;
- made arrangements for succession planning to prepare for the eventual loss of key resource – not just in the near term, but also in order that it can deal with potential difficulties in the supply of competent resource until the site is de-licensed;
- has the licensee made provisions to assess the competence of persons with changed roles, and identified additional or changed training needs;
- has the licensee taken steps to capture experienced people’s knowledge before they leave the company, and factored this into any training and assessment process. For example, part of an experienced operator's competence is manifest in the way in which procedures are interpreted (eg; how far does a handle need to be turned to crack open a valve?).

The provision of extra training for those who remain may be presented as enabling the change – but although training is likely to be an essential element of any change process, it is not the universal panacea. Indeed, focusing on training could mask deficiencies in other aspects of a licensee's proposals (eg; increases in workload; loss of experience; the dilution of skills through inappropriate use of a multi-skilling approach etc).

In my opinion the issues raised are pertinent to our workshop and I would ask to bear these points in mind as part of our discussions and in particular when drawing together the conclusions.

OPENING ADDRESS

J. Royen
Deputy Head NSD, OECD/NEA

Ladies and Gentlemen,

It is a great pleasure for me to welcome you, on behalf of the OECD Nuclear Energy Agency, to this Workshop on Assuring Nuclear Safety Competence into the 21st Century organised under the sponsorship of the Committee on Nuclear Regulatory Activities.

First of all, I would like to express our gratitude to the Hungarian Atomic Energy Authority, in particular to Dr. Lajos Vöröss, Deputy Director General and Head of the Nuclear Safety Directorate, for their kind invitation to hold the Workshop in the beautiful city of Budapest and for their warm hospitality. I would also like to thank the local organiser of the Workshop, Mr. Géza Macsuga, and his team, who worked very hard to make all the arrangements which will facilitate our life during the meeting and make it quite pleasant and efficient.

I also have to thank the Organising Committee of the Workshop, composed of Mr. Steve Griffiths (Chairman), Dr. Thomas Isaacs, Dr. Hartmut Klonk, Dr. Klaus Kollath, Mr. Géza Macsuga, Dr. Lasse Reiman and Mr. Manuel Rodriguez. They worked very hard to make the meeting a success, to identify suitable topics, to organise a programme, to approach possible speakers. Their tasks will not be completed with the closure of the Workshop. On Friday, they will sit together with the Session Chairmen to discuss the outcome of the meeting and draft a summary and conclusions for the NEA Committee on Nuclear Regulatory Activities.

As mentioned by the previous speaker, the idea of holding the meeting germinated in the report on New Future Nuclear Regulatory Challenges published by the CNRA in 1998. The report identified the human element as one of the most critical aspects of maintaining regulatory effectiveness, efficiency and quality of work Regulatory staff training and maintaining technical capabilities are significant challenges. Quality organisations require well educated, well trained and well motivated staff. Due to lack of new plant licensing and/or construction in most OECD Member countries, new staff have no experience in how to do a regulatory review. Moreover, in the absence of good corporate memory, new staff tend to ask old questions which may burden operators unnecessarily. The overall objective should be to preserve among the staff a collective knowledge in all relevant technical disciplines with sufficient depth to permit adequate independent assessment of safety issues.

In most countries, national R&D programmes are being reduced to such a point that forming an independent regulatory position might be in jeopardy. If a significant problem occurred over the next ten years, there might not be sufficient knowledge and capability to deal with it in a timely manner if the current trend continues.

With the nuclear industry in many parts of the world in decline, there is concern as to where the next generation of nuclear engineers will come from. How shall we be able to get the right caliber of staff into an industry with an uncertain future? The availability of higher education courses in nuclear engineering is declining in many countries with nuclear industries. If this continues where will future nuclear engineers receive their grounding in the subject? How will the industry and regulators continue to attract high caliber qualified recruits? Another issue is how to implement structured training programmes and how to measure their effectiveness.

Of more immediate concern are the effects of a reduction in technical competence within operators caused by reduction in numbers and the possibility of a greater turnover of staff, with the likelihood that the more able qualified personnel will move to other industries or seek early retirement if of the right age.

The changes associated with electricity market deregulation and restructuring of the electric utility industry have operational and economic consequences that may have a strong impact on the maintenance of safety research capabilities and facilities. Nuclear regulatory authorities have expressed concern about massive reductions of staff as some of these have caused shortages in vital expertise.

Dwindling resources and support as well as stagnant nuclear programmes may lead to untimely shutdown of essential large experimental facilities and the breaking up of experienced research and analytical teams with the consequent loss of competence and reduced capability to deal quickly and efficiently with future safety problems.

These issues, and others, will be discussed during the Workshop. Let me stress that discussion periods are absolutely essential in this kind of meeting. Speakers should keep the presentation of their papers under twenty minutes in order to allow enough time for the discussion. Our Workshop has a shortcoming that we can turn into a major advantage: we are not very numerous. Actually, we expected more participants, and we expected that a wider spectrum of countries would be represented. Our relatively small number should make the discussion livelier and more convivial. No doubt, the present meeting will be followed by other initiatives.

This meeting is your meeting. It will be as fruitful and as interesting as you will make it.

I wish you a most useful Workshop, and a good stay in Budapest.

INTRODUCTORY SESSION
(Invited Papers)

Chairman: Dr. L. Vöröss

BACKGROUND TO THE WORKSHOP: PURPOSE AND OBJECTIVES

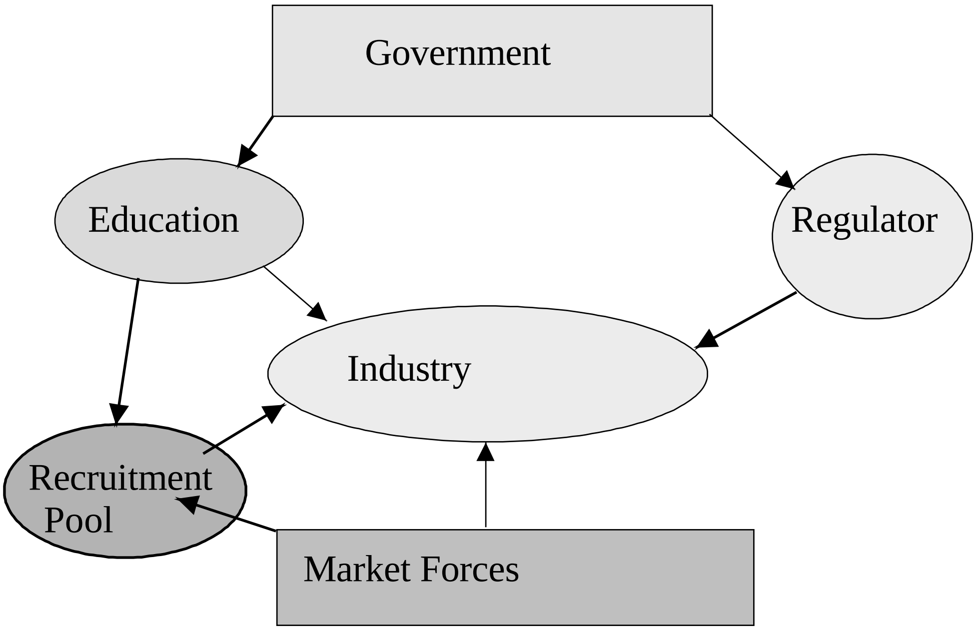
J. S. Griffiths
Chairman of Organising Committee

In its report on future regulatory challenges, CNRA identified the human element as one of the most critical aspects of maintaining regulatory effectiveness, efficiency and quality of work. There is a need to preserve among the staff a collective knowledge in all relevant technical disciplines with sufficient depth to permit adequate independent assessment of safety issues.

Quality organisations require well educated well trained and well motivated staff. In some countries national R&D programmes are being replaced to such a point that forming an independent regulatory position might be in jeopardy. If a significant problem occurred over the next ten years there might not be sufficient knowledge and capability to deal with it in a timely manner if the current trend continues.

It is against this background that CNRA recommended this workshop should be organised to consider these human issues in relation to maintaining corporate knowledge, both within the industry and regulatory bodies. This is a complex issue as there are different circumstances in each country arising from the status of the industry and its economic and political interactions. A simple model for considering these interactions is set out in Figure 1.

Figure 1. **Interactions**



This is a very simplified position but it does illustrate the position and the stakeholders involved. Overlayed on this there is also the issue of availability of technical facilities and of course finance for their maintenance. In trying to develop the workshop the organising committee tried to home in on some of the key inputs in each of these areas. Firstly there needed to be an understanding of the nature of the problem and provide some baseline information from which participants can discuss in more detail options which are appropriate in their country. This information is aimed at covering, the educational aspects, the technical needs and the human resources aspects particularly in relation to the changing management arrangements within the industry to respond to the external market. It was clear that the traditional thinking and mode of operation of the past had to change and that new ways of working within the industry as a whole had to develop.

Education and training

Education and training is a principal input into this topic. It has an impact in terms of training of staff to be recruited and in continuing training of staff once in post. The changing nature of the industry is affecting the educational establishments and long term may impact on how they teach and or lead to reduction in numbers of courses. The organising committee therefore saw a need to establish:

- Country positions and good practice in education and recruitment;
- Approaches to attracting young people into nuclear technology;
- Methods of developing relationships between universities and employers;
- Broadening of capabilities, the changing requirements of education.

This could not be examined in isolation, as there are environmental factors that impact on the Educators and the industry. The future demands need to be known if the Education system is to match the needs. Relevant factors are

- Loss rates and ageing of expertise;
- Resource availability across the whole nuclear community;
- Time frame, including time frames across Member Countries before expertise is lost;
- De-regulation and Privatisation;
- Reasons for the downturn (political, costs, competition);
- Industry needs;
- Absence of nuclear development programmes;
- Why this is a safety problem.

The purpose of the workshop is to help develop solutions so there is a need to be forward looking hence the objective was to try and establish solutions to improve the situation by exchange of good practice.

Development of existing safety capabilities

The second area that the organising committee looked at was look at the operator's and regulator's organisation. The aim is to establish methods in place to preserve and develop technical competence. This would include trying to identify specific competence shortfalls and human resource development programmes. Again the aim is to identify good practices and make recommendations.

There has to be a forward look and learn from the experiences of the changes that have been happening. This is the most difficult aspect. Information will be presented on the workforce profiles and across the community and the challenges reviewed with the aim of drawing together conclusions. Again a wide list of topics was identified.

Training programmes

- Structured training programmes implementation.
- Training programmes effectiveness assessment.
- Training programmes ageing and renewal.
- On the job training.

Maintaining competences through participation in:

- Professional & technical societies activities.
- International standard problems.
- Periodic safety reviews.
- Certification of new designs.
- Standard review plans development.
- Periodic review of plant documents and procedures.
- Interchange of staff.
- Sharing facilities.
- International exchanges/sharing to maintain capabilities.
- Joint research projects, in particular international projects.

Most of this work can be described as data gathering. The objective is to try and develop solutions in terms of either good practice or sharing of understanding. Finally the most difficult step is to look ahead at the future regulatory challenges and to try and undertake the matching exercise. This will not be easy but the aim is to use the information gathered so that ideas can be generated which can hopefully be developed into programmes within each country or through collaboration on a more international scale.

To help provide a focus I have taken some information from one of my colleagues who specialises in the area of human safety performance and safety culture. He presented a paper on organisational change in which he set out a number of factors that regulators would look for with respect to demonstration of management of change. The particular aspects concerning human issues are;

- the need to ensure that appropriate competencies are retained within the organisation (or are demonstrably accessible by it) to deal with current and future safety-related operational, technical and organisational needs;
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The provision of extra training for those who remain may be presented as enabling the change - but although training is likely to be an essential element of any change process, it is not the universal panacea. Indeed, focusing on training could mask deficiencies in other aspects of a licensee's proposals (e.g.; increases in workload; loss of experience; the dilution of skills through inappropriate use of a multi-skilling approach etc.)

In my opinion the issues raised are pertinent to our workshop and I would ask to bear these points in mind as part of our discussions and in particular when drawing together the conclusions.

NUCLEAR REGULATORY CHALLENGES OR WHO SHOULD WE TRAIN AND WHY – A REGULATORY PERSPECTIVE

Jim Furness
HM Deputy Chief Inspector
Nuclear Installations Inspectorate (NII)
St Peter's House, Balliol Road, Bootle
Merseyside L20 3LZ
United Kingdom
linda.colley@hse.gov.uk

Abstract

The understanding by the staff who design, construct, commission, operate and decommission our nuclear installations of the safety cases for the plants is crucial to nuclear safety. The lack of such understanding has been a major contributor to accidents at Windscale, Three Mile Island and Chernobyl, and may also have played a role in the recent criticality accident at Tokaimura.

Competence is not only a matter of knowledge, but also of behaviour at the level of the individual and the organisation. It is also important for those in Government departments who sponsor or regulate nuclear power. The right competence is an essential ingredient in achieving a health safety culture at all levels.

Staff turnover will be high over the next 5-10 years and the long experience of those who will be retiring must somehow be transferred to those who remain and who will be recruited. Competitive pressures may accelerate this process, increasing the stresses on the staff concerned. Plants are ageing and workloads increasing, making safety culture all the more important. "Soft skills" are as important as technical knowledge and should be included in training programmes at all levels.

1. Introduction

The sub-title of this paper is “Who should we train and why?” The answer to this question is relatively simple, and this paper is structured accordingly. It deals first with existing staff who design, construct, commission, operate and ultimately decommission our nuclear plants; this leads naturally on to the need to provide training for their successors. Secondly, the paper refers to the need for certain attitudes, culture and realism at the level of the organisation and its senior management. And finally it deals with the responsibilities of government and government departments in creating the right climate in which to foster safety culture by being proactive about nuclear power and in meeting the training needs of those who most influence its safety.

The understanding by the staff at nuclear installations of the safety cases for the plants which they operate is crucial to nuclear safety. Over the decades, a lack of understanding of safety cases among the staff concerned appears to have been a major contributor to nuclear accidents at Windscale in 1957, at Three Mile Island in 1979 and at Chernobyl in 1986. Initial reports suggest that this may also be true for the accident at Tokaimura in Japan two weeks ago. This applies to those who design, construct, commission, operate and ultimately decommission our nuclear plants.

There is a continual need to identify the gap in knowledge and behaviour between what exists and what we would wish to exist, both now and in the future. Competence is not only a matter of knowledge, but also of behaviour - how the knowledge is applied, both at the level of individuals and of the organisations in which they work.

There is common recognition of the need to enhance safety culture within our organisations. The report prepared by Tom Murley for the CNRA’s meeting in June this year spoke of “an organisation’s basic safety values, attitudes toward conservative operation, quality, professionalism, continuous learning and improvement processes” as being the hallmarks of a sound safety culture (Murley, 1999).

Whilst many of the papers prepared for this workshop refer to knowledge and how it can be passed on to those starting out in their nuclear careers, it should never be forgotten that all the knowledge in the world is of very little practical use unless it can be translated into the appropriate behaviour needed to ensure nuclear safety.

2. Forecasting future needs

Thus the starting point for any consideration of nuclear safety competence is to examine our organisations as they are today to establish the extent of any competence gap between what we have and what we would wish to have. This exercise, sometimes called a “training needs analysis” sets the baseline programme for existing staff by establishing the desired competences for each position within the organisation and comparing it with the current competences of the individuals holding those posts. At the same time, it is vital to check that the existing organisational structure, in terms of reporting lines and numbers of staff in each of the functions, is adequate to deliver what is required.

Through this process, a baseline competency matrix is established which can be used as the template for future recruits, and for the refreshing and updating of existing staff.

Using the competency matrix and the succession planning process enables a forecast of future recruitment and training needs to be established. A number of papers to be presented at this workshop describe how this training is provided in different countries, both for students in the form of graduate and post graduate training, and for those already working in the nuclear industry. A common theme running through the papers is of a nuclear industry in the West with little new building going on, or in prospect. The situation is brighter however in the Far East, with building of new nuclear power plants of advanced designs continuing.

However the situation is not static in the West. Many of the industry's current workforce will be retiring in the next 5-10 years, and this intensifies the need to capture their knowledge and experience for transfer to the next generation of nuclear workers.

3. A changing nuclear industry

In addition to the handover of existing knowledge, there is also the need to adapt to changing circumstances. In many Western countries, energy markets are becoming deregulated, and nuclear power is having to face up to stiff competition from other fossil fuels, particularly gas. Gas fired power stations are quicker and cheaper to build, as well as being cheaper to run than nuclear stations. Without some form of carbon tax to reduce carbon dioxide emissions, it is difficult in the short and medium term to see significant commercial investment in new nuclear power plants. The only exceptions to this somewhat gloomy picture may be where design consortia wish to build demonstration prototypes to prove new designs and to keep alive key manufacturing skills and facilities.

With the notable exception of France, the nuclear sector is smaller than that of other energy sources, and in a deregulated market, nuclear power generators become "price takers" rather than "price makers". Profitability is thus dependent upon reducing generating costs and increasing electrical output. The pressure to reduce costs has led in turn to reductions in the numbers of operating staff at the power plants and support staff within technical support organisations. Reductions in staff directly employed by licensees are resulting in a greater dependence upon contractors – hired and fired when required.

Alternative arrangements are also being pioneered to provide licensees with greater assurance that services will be available when required, and to provide contractors with greater stability – partnering, joint venture support companies, long term support agreements etc. All of these changes tend to put additional demands on the staff who remain. They are required to be competent across a wider range of disciplines, to learn new skills, including procurement and contract management, and to be an "intelligent customer" for the goods and services which the licensee buys in.

As well as reducing the numbers of staff employed, increasing competition provides strong incentives to increase electrical output, by using longer fuel cycles, reducing conservatism in operating conditions and by shortening outage times. Whilst regulatory bodies in each country are well aware of the economic realities faced by nuclear licensees, there must be at least a slight suspicion that increased pressures for higher outputs and lower costs may lead to some cutting of corners and erosion of safety margins. Staff, both old and new, have to be constantly on their guard against any such erosion of safety margins, and it is essential that the safety culture in the organisation allows the questioning attitude – one in which to quote Tom Murley again:

> "workers are free to raise safety concerns without fear of retribution". (Tom Murley)

4. Ageing nuclear plants

The other reason why the questioning attitude is so important is that our power plants are not getting any younger. We in the UK are still operating the world's oldest civil nuclear power plant, now 43 years old, at Calder Hall. Other plants round the world are approaching their 40th birthday, and life extension is a big issue for a number of countries. The concept of a 10 yearly periodic safety review is now widely accepted and is a powerful tool with which to identify ageing mechanisms. Engineering and technical staff need to be aware of current best practice in terms of plant design and operation, and also in terms of the content and structure of the safety case. They must be experts in fatigue, vibration, creep, corrosion, cracking, neutron embrittlement, deterioration of civil structures, degradation of electrical equipment such as cabling, switchgear, relays and transformers, and the potential obsolescence of instrumentation, computers and protection system components, all of which can lead to plant degradation.

When existing plants reach the end of their useful lives and control rods are inserted for the final time, staff will need new competences to decommission them, to handle and dispose of the radioactive waste which this produces, and for site remediation.

Thus the competences required of staff as plants move inexorably towards the end of the bathtub curve will constantly change. Ageing plants may well need more staff to keep them running, to carry out the necessary upgrades, and ultimately for their decommissioning.

5. Implications for licensees

Up to this point this paper has covered the challenges which will face individual staff, the small teams in which they work, and the competences they will require to assure nuclear safety into the 21st century. However, efforts by individuals or by teams will be ineffective unless the right safety culture is encouraged and fostered at the level of the organisation ie. the licensee, and by relevant government departments, including those which sponsor and those which regulate the nuclear industries in their respective countries.

Licensees, and relevant government departments also need to be learning organisations. They need to recognise that plants nearing the end of life may not be able to keep costs down at the levels achieved when those plants were young. The work required to write safety cases justifying life extension and the costs of carrying out any required plant upgrades can ultimately make continued operation uneconomic. Funds for decommissioning, site remediation and radioactive waste disposal must also be set aside during life.

Organisations need to be realistic about future costs, drawing on the experience of others to ensure adequate contingencies have been provided in financial modelling. Research, experiments and modelling can all be used to do accelerated testing of materials and components so as to increase the reliability of predicting the date at which deterioration of safety critical components makes further operation unacceptable on safety grounds, or no longer viable on economic grounds.

6. Considerations when down-sizing

Organisations need to learn from the mistakes and experiences of other when considering the potential effects of changing organisational structures or resource levels. Safety is achieved not only by having individuals with the right competences, but also by having the right number of such individuals in the right place at the right time. “Down-sizing”, or “right-sizing” as it is sometimes euphemistically called, can put individuals at all levels under severe stress, particularly when they are having to cope with abnormal situations on the plant. Stress leads to mistakes. Changes to resources and organisation structures need therefore to be made cautiously. Those wanting a quick insight into the Ontario Hydro problems should read the account by Kirsten Dahlgren, IAEA (Dahlgren, 1998).

A number of the papers to be presented at this workshop will refer to the difficulty of recruiting appropriate staff to what is perceived as a declining nuclear industry. Recruitment to compensate for natural retirements of staff will be hard enough without compounding the problem through ill conceived down-sizing exercises, which often result in the loss of those staff having most experience. Such staff should, in the years before retirement, be used to mentor new recruits, passing on their experiences and capturing past knowledge of the plant, its performance and its idiosyncrasies for future generations.

Organisations are the primary determinant of safety culture. Leadership, and the setting of expectations, comes from the top. The best organisations work hard at improving the “soft skills” of their staff as well as their theoretical knowledge. Team working, problem recognition and understanding the importance of working in accordance with written procedures can all be taught, and when combined with high staff morale can have a profound effect on both nuclear and conventional safety.

7. Implications for governments

Where then does this leave the last element in the triangle, Governments and governmental departments? Other papers refer to the influence of Government policy and funding for University undergraduate and particularly post graduate courses. Research reactors, many of which were attached to University departments, are closing down. Professor Goddard refers to the last operating research reactor in the UK at Imperial College; several others have shut down in the last 10 years. These reactors allowed students to gain real experience in reactor physics, measuring and dealing with radioactivity, making radioisotopes, etc. They also allowed the training of significant numbers of students from other countries who have subsequently helped in the safe development of peaceful uses of nuclear power in their own countries.

Governments enact laws, under which nuclear plants can be licensed, and laws relating to protection from ionising radiation. Governments also have the ability through policy decisions, legislation and taxation to tip the scales in favour of, or against, the use of nuclear power. Governments can influence public opinion and set expectations as to the levels of risk which can be tolerated. Governments have the power to accept or reject the views of those opposed to nuclear power generation, or to nuclear fuel reprocessing. In other words, Governments set the climate in which nuclear power is seen as having long term, rather than short term financial and job prospects.

Ultimately government attitudes will have a major influence on the nuclear industry’s ability to recruit postgraduate staff with nuclear training. If nuclear postgraduate courses are not available, the industry will have to the training itself, with the consequent risks of narrowing the vision of the students involved. This is not to criticise the extensive training which the industry carries out, but it tends not unnaturally to be focused on the needs of specific jobs eg. desk operators, health physics monitors etc.

External courses are invaluable for such subjects as criticality, shielding and reactor physics, where the economies of scale make it sensible that training is done on a national or international basis.

8. Conclusions

This paper has referred to:

- the importance of an understanding of the plant safety case for all staff if nuclear accidents are to be avoided;
- competence being a combination of knowledge and behaviour;
- the importance of competence, when defined in this way, for the safety culture of the organisation;
- the requirement for a “training needs analysis” and proper succession planning;
- the need to adapt to increasing competitive pressures whilst preserving and enhancing safety culture;
- potentially greater workloads on staff, and increasing operating costs, as plants grow older;
- the right number of competent staff in the right place at the right time;
- the difficulty of reversing inappropriate down-sizing;
- the importance of soft skills such as team working;
- the role of Governments in setting the climate for nuclear power;
- the role of Universities and other Institutions in providing specialist post graduate training in nuclear engineering and nuclear physics studies.

Mr Kent Hamlin, Deputy Director of WANO, the World Association of Nuclear Operators, at a seminar in London two weeks ago, quoted Robert Franklin, the former Chairman of Ontario Hydro, who said:

> “If you pursue safety, you get efficiency.
> If you purse efficiency, you get an accident”. (Robert Franklin)

It is important that both regulators and licensees remember these words as the drive to bring down costs continues, and that we ensure that all involved in the industry, whether licensees, contractors or regulators continue to put safety at the top of the nuclear agenda.

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SURVEY AND ANALYSIS OF EDUCATION IN THE NUCLEAR FIELD

T.H. Isaacs
Director
Office of Policy, Planning and Special Studies
Lawrence Livermore National Laboratory
7000 East Avenue, L-019
Livermore, California, USA
isaacs2@llnl.gov

Origins

- Convened by the Nuclear Energy Agency.
- Reflects concern regarding the adequacy of nuclear education.
- Representatives from 17 countries and the European Commission.
- Began in Spring 1998.

Objectives

- Survey the status and trends of nuclear education and training.
- Identify prominent problems.
- Learn from success stories in motivating young students.
- Suggest possible actions.

Member Countries

European Commission and…

- Belgium
- Canada
- Czech Republic
- Finland
- France
- Germany

- Hungary
- Italy
- Japan
- Korea
- Mexico
- The Netherlands
- Sweden
- Switzerland
- Turkey
- United Kingdom
- United States

Status

- Organising meeting: March 1998.
- Questionnaire developed and distributed to universities, industry, national labs.
- Analysis completed.
- Final report: Fall 1999.

Facilities

- Research and Training Reactors
  - Average age is 33 years.
  - Seven decommissioned or under decommissioning (1990-1998).
- Hot Cells
  - Average age is 28 years.
  - Three decommissioned or under decommissioning (1990-1998).
- Radiochemistry Labs
  - Average age is 24 years.
  - Two labs have been opened (1990-1998).

Occupations

- Undergraduates
  - Continued studies.
  - Electric utilities.
  - Non-nuclear manufacturer.
  - "Other."

- Masters
  - Continued studies.
  - Electric utilities.
  - Nuclear manufacturer.
  - “Other.”
- Doctorate
  - Academic career.
  - Nuclear research institute.

Training

- Mostly for in – house employees.
- For new and experienced staff.
- Aimed at specific functions.
- Most reported as “good” or “satisfactory”.

Points of Relative International Consensus

- Undergraduate programmes in decline.
- Less specialisation in classical nuclear engineering.
- More variety in nuclear courses to attract broader range of students.
- Emphasis on nuclear safety, waste management, radiation physics, medical applications, and more.
- Departments under pressure – being merged and/or under threat of elimination.
- Master's and PhD programmes somewhat more stable.
- Faculties and facilities aging.
- Reduced government and industry support.

The Health of Nuclear Engineering at Universities

- “Given low enrollment, long-term survival of the programme is questionable.” (Belgium)
- “The threat scenario is that the increasing retirement happens together with a decreasing interest of the younger generation in the nuclear field.” (Finland)
- “Perhaps in the next few years, the educational programmes may not be able to survive.” (Sweden)
- “Universities are suffering from the general public mentality against basic research in general and against nuclear basic research in particular.” (Switzerland)
- “The condition of “traditional” nuclear engineering training is very poor, with only one MSC course and some undergraduate taster modules.” (UK)

Employment Opportunities

- "… despite its low value, the number of graduates seemingly still largely exceeds the needs of the nuclear energy industry." (Belgium)
- "All our graduates find easily positions in nuclear fields." (France)
- "The graduate programme is just maintained and is providing qualified manpower, but there are almost no job openings and opportunities..." (Korea)
- "Now it is more than needed, in the near-term programmes it will not be sufficient." (Spain)
- "The current level of nuclear education is sufficient for the supply of manpower caused by retirement..." (Sweden)
- "Current level of nuclear education seems – at the moment – to be sufficient." (Switzerland)
- "… there has been a very good uptake rate of graduates by the industry coming from specialized masters level courses." (UK)

The U.S. Job Market

- "Our students have great difficulty in finding jobs in the nuclear industry..."
- "The market for nuclear engineers has not been better. We are placing all our students, even our lowest average students, in challenging positions."
- "The undergraduates know their job market is very good at the moment. This has not increased enrollment."
- "Today the manpower supply and demand may be just balanced, but there is evidence that an increased demand ... will create shortages of needed nuclear engineers."
- "We have seen a sudden and dramatic increase in entry-level positions…"
- "… a prevailing perception that the job market is poor for nuclear engineers, while the reality is that the market is currently very good."

Key Insights (Tentative)

- Poor public perception about things nuclear.
- Seen as a declining field by prospective students; recruitment is difficult, particularly best students.
- Changes in curricula modestly successful in retaining student populations.
- May no longer be a sufficient supply of nuclear engineers to meet industry needs; student interest for education lags industry needs.
- A well-advertised, stable job market is needed to attract and hold students
- Students and the public need to be made aware of the important positive aspects of nuclear, the variety of good jobs available, and the financial and other support available

- Financial support and other proactive efforts by government, industry, academia, and national laboratories have been instrumental in maintaining many nuclear programmes.

"A very gloomy view indeed, especially from inside the university community. However, we need to consider very carefully what the actual needs are, who the 'end user' is and the position of the industry's own in-house training programmes. In the UK, with no design development and the industry contracting and becoming ever cost conscious, recruitment is at a low level. There would thus seem to be no prime face case for a very strong university element in nuclear power education." (UK)

Collaborations

- Part-time lecturers from industry.
- Cooperative research.
- Theses in research institutes or industry.
- Industry sponsorship of students.

Possible Recommendations

Government Support

- Long-term, high-risk, high-reward endeavor.
- Stewardship as new challenges emerge.
  - Ageing and retiring facilities and personnel.
  - Relicensing.
  - Waste management and disposal.
- Insurance for long – term needs.
- International influence to assure proper operations.

Possible Recommendations

- Academic.
- Interactions early and often – "Touch Hardware and People."
  - e.g., use of Web, contact with high school candidates, summer courses and jobs, internships and research with faculty, general introductory courses.
  - International collaboration on exciting projects – opportunity, visibility, innovation, cost effective.

NUMERICAL DATA

Table A1. The number of participants in study by country and organisation.

	University	Research Institute	Power Company	Manufacturer	Engineering Office	Regulatory Body	Others	Total
Belgium	7	1	1		1	1		11
Canada	7							7
Finland	3	2	2		1	1		9
France	4	1		2	1			8
Hungary	4	3	1	1				9
Italy	6	1		1				8
Japan	21		8	8				37
Korea	6	1	1					8
Mexico	4	2	1			1		8
Netherlands	1	1	1		2			5
Spain	6		1				1	7
Sweden	7		4			1		12
Switzerland	9	1	4			1	4	19
Turkey	5	1				1		7
United Kingdom	9	1	1	1		1		13
United States	22(50)	2	(a) 5	2	1	1		33
TOTAL	121(149)	17	30	16	6	8	5	201(229)

The numbers in the parentheses include the number of universities whose data refer to the another survey by USDOE.
(a) INPO provided the corrective answer of US utilities. Four also provided individual responses.

Number of students in 1990 and ratios in 1995 and 1998 to 1990

	Undergraduate			Graduate-Master			Graduate-Doctor		
	1990	1995	1998	1990	1995	1998	1990	1995	1998
Belgium	15	**1**	**0.53**	38	**1.45**	**0.79**	1	**1**	**1**
Finland	0	-	-	0	-	-	0	**1**	**0.93**
France	55	**1.15**	**1.02**	257	**1.28**	**1.18**	60	**1.87**	**1.25**
Hungary	120	**1.25**	**1.42**	24	**2.17**	**3.04**	12	**1.5**	**1.08**
Korea	544	**1.07**	**0.97**	65	**1.17**	**1.43**	26	**1.12**	**1**
Mexico	22	**0.91**	**0.95**	12	**1.58**	**1.5**	0	-	**1** *
Netherlands	0	-	-	6	**0.67**	**0.67**	8	**1**	**0.75**
Spain	65	**1.52**	**2.8**	74	**1.34**	**1.34**	73	**1.03**	**1.01**
Sweden	78	**1.63**	**1.42**	9	**5.67**	**4.22**	17	**2.53**	**2.29**
Switzerland	104	**2.34**	**1.06**	29	**1.07**	**0.93**	27	**1.17**	**1.31**
Turkey	146	**1.29**	**1.03**	147	**1.35**	**1.42**	30	**1.63**	**1.73**
United Kingdom	864	**1.2**	**1.32**	73	**1.05**	**1.07**	63	**0.89**	**1.16**
United States	1398	**0.73**	**0.41**	722	**0.83**	**0.64**	701	**0.83**	**0.7**

*Ratio to 1995

Preliminary, incomplete data

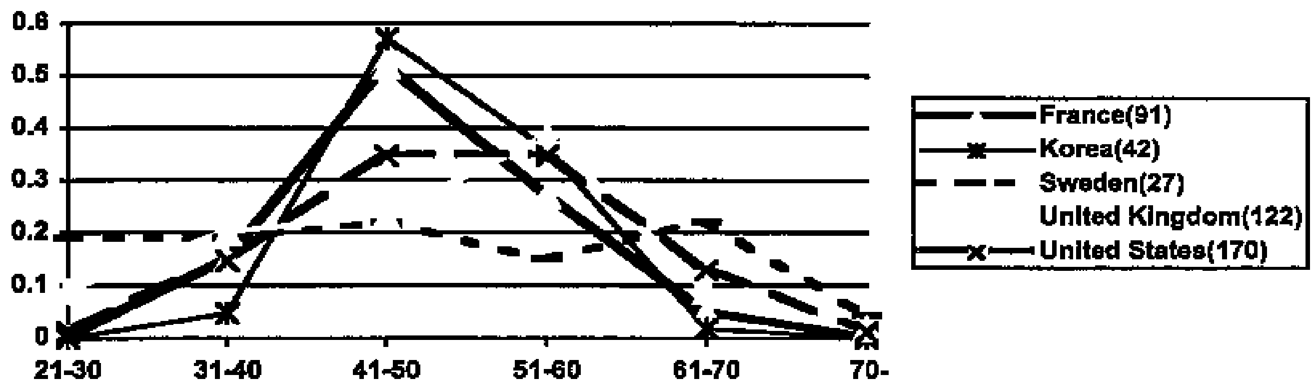
Ratio of the number of full time faculties to 1990

	1995	1998
Belgium	0.5	1
Finland	1	1
France	1.42	1.79
Hungary	1	0.98
Korea	1.08	1.14
Mexico	1.12	1.25
Netherlands	-	-
Spain	1.07	15 *
Sweden	1.29	1.43
Switzerland	0.92	0.92
Turkey	1	0.85
United Kingdom	0.9	0.76
United States	0.92	0.87

*One university reported only the numbers for 1998

Preliminary, incomplete data

Age structure of faculties in countries whose nuclear capacity are over 10GW



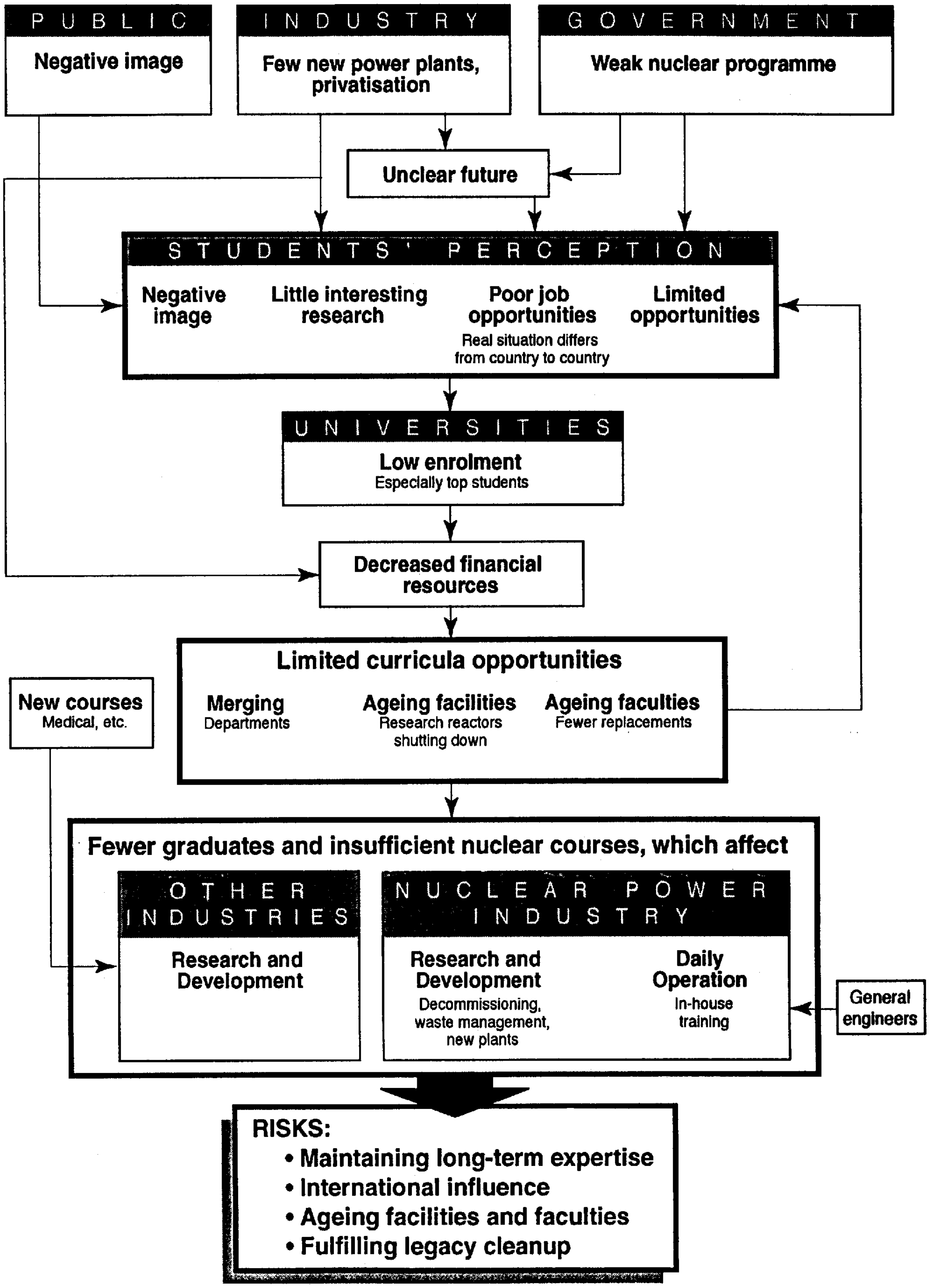
The parenthesis indicates the number of faculties

Preliminary, incomplete data

Age structure of faculties (ratio)

Country	21-30	31-40	41-50	51-60	61-70	70-
Belgium	0.04	0.01	0.32	0.46	0.17	0.00
France	0.00	0.15	0.52	0.27	0.05	0.00
Hungary	0.07	0.16	0.33	0.30	0.14	0.00
Korea	0.00	0.05	0.57	0.36	0.02	0.00
Mexico	0.00	0.20	0.52	0.18	0.09	0.00
Netherlands	0.00	0.60	0.00	0.40	0.00	0.00
Spain	0.02	0.46	0.25	0.16	0.11	0.00
Sweden	0.19	0.19	0.22	0.15	0.22	0.04
Switzerland	0.27	0.14	0.27	0.27	0.06	0.01
Turkey	0.16	0.38	0.28	0.15	0.03	0.00
United Kingdom	0.09	0.20	0.23	0.38	0.09	0.02
United States	0.01	0.15	0.35	0.35	0.13	0.01

Preliminary, incomplete data



PUBLIC
Negative image
INDUSTRY
Few new power plants, privatisation
GOVERNMENT
Weak nuclear programme
Unclear future
STUDENTS' PERCEPTION
Negative image
Little interesting research
Poor job opportunities
Real situation differs from country to country
Limited opportunities
UNIVERSITIES
Low enrolment
Especially top students
Decreased financial resources
Limited curricula opportunities
Merging
Departments
Ageing facilities
Research reactors shutting down
Ageing faculties
Fewer replacements
New courses
Medical, etc.
Fewer graduates and insufficient nuclear courses, which affect
OTHER INDUSTRIES
Research and Development
NUCLEAR POWER INDUSTRY
Research and Development
Decommissioning, waste management, new plants
Daily Operation
In-house training
General engineers
RISKS:
• Maintaining long-term expertise
• International influence
• Ageing facilities and faculties
• Fulfilling legacy cleanup

STATUS OF NUCLEAR ENGINEERING EDUCATION IN THE UNITED STATES

Gilbert J. Brown, Ph.D.
University of Massachusetts Lowell
Lowell MA 01854
USA
Gilbert_Brown@UML.edu

United States

Nuclear engineering education in the United States has shown a marked decline in the past decade. The number of university programmes, student enrolments. degrees granted and university research reactors have all decreased sharply. There is evidence of an ageing faculty demographic and few junior faculty students being hired. The ability to maintain the educational infrastructure capable of supplying well – educated nuclear engineers for the existing and future nuclear industry is in peril if the current trends continue.

The nuclear electric power situation

There have been no new nuclear electric power plants ordered in the United States since 1978 and the last reactor ordered that eventually was put into operation was in 1974. However, since 1980, 40 U.S. nuclear power plants have entered service. At its peak, 110 plants were operating, the number now standing at 103. Industry capacity factors have increased from about 55% to about 75% in the past 20 years; however, electricity restructuring adds a degree of uncertainty about future operations, decommissioning and license renewal of existing plants and the building of new plants.

The accident at Three Mile Island and the devastating accident at Chernobyl stimulated negative opinions toward nuclear energy. However, recent public opinion polls show a clear majority favouring the continued use of nuclear power, the extension of licenses for operating plants, and keeping the option available for new plants in the future. This occurs despite the U.S. programme for permanent disposal being well behind schedule, resulting in a continuing build-up of spent fuel at commercial reactors throughout the United States.

Thus the near-term outlook for nuclear power is often characterised as stagnant at best and in serious decline by others. Such perceptions have clearly played a role in the dramatic reductions in enrolment captured in the survey. Many respondents commented that students were reluctant to choose a nuclear curriculum because of the perception that the job market and longer term outlook for nuclear engineers were poor or because they saw an “occupational stigma”. Ironically, at the same time, many nuclear department heads responded to the survey by indicating that the job market was strong and that they now did not have enough graduates to meet demand.

This continuing mismatch occurs at a time when the horizon begins to show a broad range of new nuclear challenges, independent of when and whether there is a short-term return to new nuclear power plant growth. Understanding the ageing of existing plants, moving to relicense them for extended operation, the shutdown and decommissioning of some older plants, the cleanup, decontamination, and management of wastes are just some of the important emerging issues which will require an expert workforce for decades. This arises at a time when the workforce is ageing and many nuclear departments have either closed, merged with other departments, or broadened their curricula to appeal to a wider student and industrial community.

The survey

During the period surveyed, 1990-1998, the trend in nuclear education and training in the United States was generally one of decline and consolidation. Undergraduate enrollment declined from 1400 to fewer than 600, with master's and doctorate enrollments falling by about one-third. An understanding of events that transpired before and during the survey periods is helpful in properly understanding the data and in reaching conclusions about appropriate future actions.

The number of university nuclear engineering programmes has dropped from 59 to 33, with one university closing its programme this past year. From a high of 64 university research reactors, the United States now counts only 28 reactors on 26 campuses. In the last two years, four university research reactors have been abandoned by universities who do not see the financial payback of operating these reactors nor the scientific necessity due to the lack of students and users. Almost all the remaining facilities are more than 20 years old.

With the number of undergraduate nuclear engineering students declining precipitously over the survey period and the advanced nuclear engineering numbers dropping more slowly, the universities have responded in an attempt to make nuclear engineering a more appealing field of study. Some have broadened their nuclear engineering curricula beyond the electric power aspects to include topics such as radiation health physics, radiation science, waste management, environmental effects, space applications, medical science, plutonium disposition and probabilistic risk assessment. One university merged its Nuclear Engineering and Engineering Physics programme with the Environmental Engineering programme and now offers degrees in nuclear engineering, engineering physics, and environmental engineering. Another university moved the Radiation Health Physics from the College of Science to the department of Nuclear Engineering. Others have had their nuclear engineering departments merged with other engineering departments, some creating nuclear engineering options rather than entire curricula.

This array of scientific fields is intended to appeal to a larger campus-wide audience and is designed to attract students from a variety of undergraduate degree programmes. Survey results were mixed as to the effectiveness of this approach, although many believed that the decline in enrollment had been stopped or even reversed.

The number of faculty among the remaining departments declined modestly over the survey period. There were instances reported of new faculty hiring. In areas where programmes were merged and broadened, the number of faculty available to educate those pursuing a profession may have increased. The age profile of faculty were evenly split with 35% each in the 41-50 and 51-60 age ranges, older than those reported by most other countries, and only 16% of faculty under 40.

The number of non-university respondents to the survey was comparatively small and as such the number of responses to the level of training offered by companies was meager. Most considered training to be well structured and important to the state of the art. Training occurred through on the job experience or instruction and job rotation assignments. Compared to 1995, the training activities available in the United States were, like most countries of the survey, decreasing. The peak age of the instructors was in the 41-50 category, but with a large percentage in the 31-40 category, an encouraging sign in an industry not known for youthful demographics.

Actions taken

There has been a degree of innovation shown most evident in the area of recruitment. Schools have advertised their programmes through the distribution of literature on career opportunities, newsletter publications, outreach to high schools, open houses for freshmen, summer programmes and tours of the campus, mailings to potential students, and recruiting posters. In addition, schools have held seminars on opportunities in the nuclear industry to community colleges, emphasising the environmental aspects of nuclear, and teacher workshops. Other steps identified in the survey have included the hiring of a full-time recruiter, advertising to local private and government organisations, visits by undergraduates and graduate students to regional high schools, advertising on the Internet, and the initiation of programmes where freshmen work on research directly with a faculty member. The results of these actions have been mixed as reported by survey respondents.

Industry has been even more active in taking steps to attract students into the nuclear field although survey results indicate that even these efforts are not very widespread. Activities range from participating in engineering week activities and advertising industry's work to college-bound students to sponsoring regional education programmes that are focused on grades K-12. These efforts include teacher training and hands-on learning experiences with a focus on building a math and science foundation. With the 7-12 grade students, technology labs, science seminars and mentoring are used to attract students into technical careers. At least one industry employer believes that utilising students from middle school through post-doctorates for research is a lever for recruiting individuals into the nuclear education path. The middle school students attend summer camps and are taught by professional scientists and taken on extended field trips to power plants, future nuclear waste repositories, etc. Younger students have the opportunity to participate, outside of their normal classrooms on a Saturday morning, in science activities. Other private companies partner with local universities to teach a nuclear seminar for teachers, while still others lecture at universities which leads to the hiring of students from the university and the sustaining of the companies manpower infrastructure. The American Nuclear Society provides over USD 110 000 in fellowships and scholarships to graduates and undergraduates studying nuclear engineering. In addition, industry through the Institute for Nuclear Power Operations' National Academy for Nuclear Training provides about one million dollars annually in graduate fellowships and undergraduate scholarships. Together, these programmes support over 185 undergraduates and 55 graduate students who are pursuing courses of study to prepare them for work in the nuclear industry.

One of the keys for faculty retention, particularly in a climate of declining enrollments, is ensuring that the faculty is self-supporting; that is, attracting research funding to the university. Obviously, universities will support faculty that can sustain themselves thus preserving the university's financial resources. A relatively new programme entitled Nuclear Engineering Education Research grants was instituted by the U.S. Department of Energy to address this need of faculty research in the area of nuclear engineering. The programme awards grants, on a peer reviewed competitive basis, to faculty members undertaking innovative nuclear engineering research in one of eight technical areas. In the first two years of the programme there have been 39 grants awarded to 39 different professors totaling USD 6.5 million for (primarily) three year research efforts. No one faculty member can be the principle investigator on more than one award and some preference is given to young investigators (those with less than 10 years of university experience) as a way to encourage the retention of these faculty members by the universities.

Efforts to increase funding for nuclear energy research and education have met recently with success. In a 1997 study by the President's Committee of Advisors on Science and Technology (PCAST), nuclear energy was identified as one of the technologies that could alleviate global climate change and address other energy challenges, including reducing dependence on foreign oil, diversifying the U.S. domestic supply system, expanding exports of U.S. energy technologies and reducing air and water pollution. As a result, beginning in fiscal year 1999, nuclear energy research and development funding (USD 19 million) was provided to the Nuclear Energy Research Initiative programme, which is designed for universities, national laboratories and industry to research, develop and demonstrate avanced technologies that address nuclear energy's key issues. Also, there has been a dramatic increase in the level of federal government funding for university nuclear engineering activities. These activities include support for students in the form of fellowships, scholarships and research funding, research funding for the faculty, fuel assistance to university reactors, and cost sharing with industry to support the nuclear engineering infrastructure at universities. In a typical year, approximately one million dollars is provided to graduate and undergraduate students by the federal government for fellowships and scholarships in nuclear engineering. These funds provide for over 20 fellowships and up to 45 scholarships. In addition, there is a programme that provides funding to the universities to encourage reactor sharing with other educational institutions and an outreach programme is planned to familiarise entering college freshman/high school seniors with nuclear engineering by providing instruction for high school science teachers at summer camps. Funding for these university programmes has grown from USD 3 million to over USD 11 million in just three years.

Outlook

Nuclear engineering education in the United States is reflective of the perceived health of the nuclear electric power industry within the country. Just as new commercial reactor orders have vanished and some power plants have shut down, so too have university enrollments shrunk and research reactors closed. This decline in nuclear trained specialists and the disappearance of the nuclear infrastructure is a trend that must be arrested and reversed if the United States is to have a workforce capable of caring for a nuclear power industry to not only meet future electric demand but to ensure that the over 100 existing plants, their supporting facilities and their legacy in the form of high level waste and facility clean-up are addressed. Additionally, the United States has an obligation to support and maintain its nuclear navy and other defence needs. And, lastly, if the United States is to have a meaningful role in the international use of nuclear power with regard to safety, non-proliferation and the environment, then it is imperative that the country continues to produce world-class nuclear engineers and scientists by supporting nuclear engineering education at its universities.

The continued support of the federal government and industry for university nuclear engineering and nuclear energy research and development is essential to sustain the nuclear infrastructure in the United States. Even with this support, and the continued excellent operation of the existing fleet of nuclear electric power plants, it is conceivable that nuclear engineering as an academic discipline may fall victim to poor communications and a tarnished public image. What is needed is a combination of federal and industrial support along with the creativity of the universities to expand their offerings to include more than power production. The objective is a positive message on careers in nuclear related fields, and recognition of the important role of nuclear energy in meeting the country and the world's energy needs, while helping to curb global warming. The redevelopment of a positive outlook for nuclear energy in the United States will encourage the recruitment and education of a new generation of students to meet the nuclear manpower needs of the next several decades.

PARTNERSHIP FOR SUCCESS: SOLVING THE PROBLEMS TOGETHER

S.E. Ion
Director of Technology and Operations
BNFL
Hinton House,
Risley, Warrington
Cheshire WA3 6AS, UK
seil@bnfl.com

My name is Sue Ion and I am a Director of BNFL with responsibility, among other things, for Research and Development. And one of the issues that I feel most strongly about, and this impacts on all my duties, is how important the people who make up the Company are. Because it is not BNFL but more correctly, the people within BNFL doing the work, who are our greatest assets. And unless we have the right mix of people, the right mix of talents, within BNFL available to us directly or indirectly through key centres of accessible excellence, then we're going to have a problem in the future.

How to attract people to join our company is a parochial issue but it does assume that there are people, importantly young people, out there who have the education and training that is relevant to our company. My concern is that may not be the case for much longer. Which is why I am here taking part in this conference, and why I believe it to be so important that the key influential bodies such as the OECD put skills and capability maintenance near the top of the agenda.

Having introduced myself now let me introduce BNFL. Just over 16 000 of us make up the Company that last year had a turnover of £1.5bn. Although we are government owned, we operate as a private company and we are expected to make a profit and pay our shareholder, the government, a dividend. As you can see our profit was over £200M and the dividend we paid was a healthy £65M. Our principal activities are fuel manufacture, engineering, reprocessing, waste management and decommissioning. We have a very healthy level of exports and of capital expenditure. Not shown here is our investment in R&D, which was £80M with a healthy £41M from profits.

Back in 1998 BNFL was a UK nuclear company with offices world wide and an American subsidiary, BNFL Inc. Since then we have acquired the UK Magnox reactors and so we can add electricity production to our list of activities. We have recently taken a major step towards becoming a major international nuclear services provider following the £1bn acquisition of Westinghouse's nuclear business with our US partner Morrison Knudsen.

We are a successful company. Seemingly we have little to worry about. However, we have some areas of concern relating to availability of skills and facilities that as an industry we have taken for granted. But before I go into detail on that let me now say something about the events that have shaped the UK nuclear industry, and which my American colleagues say apply also in the USA, so that you can appreciate my feelings of unease. You may find parallels with your own country's experience.

So, let us go back in time. Back to the 1950s. Every decade has its epithet but for those of us who now work in the nuclear industry and who are of a certain age this was the Atomic Age. That is the Queen in 1956 opening the world's first commercial reactor, Calder Hall, on what is now our Sellafield site, in the north-west of England.

Yet it was in the following decade – the one of the Beatles, Carnaby Street and hippies, the Swinging Sixties – that the UK nuclear industry really established itself. Nine commercial stations were built – the first generation of reactors, the so-called Magnox stations that we have just acquired – and more were planned. This was an era when politicians spoke of "the dawn of the age of technology", when a government report recommended the expansion of university science departments and when the public eagerly awaited news of the latest scientific and technical achievements. Yes, the government and the public actually supported science and welcomed nuclear power – how times have changed!

The nuclear industry, buoyant and self-confident was part of a brave new world that carried with it the hopes of the public, politicians, academics and its own workforce alike. Government funding supported not only the construction of the power stations but also the vital R&D that was necessary to ensure that they worked safely and efficiently. The industry was at the forefront of new and exciting technologies such as metallurgy, materials science, radiochemistry and chemical engineering as well as physics. A lot of leading edge research was done in university departments by talented academics who were keen to rise to the intellectual challenges posed by the industry. There was a vibrant academic base and degrees in subjects such as nuclear engineering and nuclear physics were popular. Internationally, Britain ranked alongside the best. Its academics were sought after and its researchers were welcomed in international collaborations.

The United Kingdom Atomic Energy Authority – better known as the UKAEA – had particularly strong links with universities. The laboratories at Harwell, with their international reputation for research, attracted a large number of academics. Indeed, Harwell and the other UKAEA research establishments were almost an extension of university departments. Like the UKAEA, the Central Electricity Generating Board (CEGB) and the builders of the nuclear power stations also had extensive links with universities as well as having their own research establishments. The government funded these agencies and as they in turn contributed to the funding of university research there was an indirect as well as direct flow of government money into the universities.

In other words there was no shortage of intellectual effort or expertise on matters nuclear and no shortage of money to ensure it flourished. It was into this atmosphere that BNFL was born in 1971, as an offshoot of UKAEA, to deal with the commercial aspects of nuclear power. The UKAEA remained the larger organisation for a number of years, concerned primarily with research, before being eclipsed by its commercially oriented offspring.

Nuclear power construction continued into the seventies – but at a reduced rate. Only four new stations came on line although another five were under construction. The first generation of reactors, the Magnox ones, had given way to the bigger and more efficient Advanced Gas Reactors. Both are uniquely British designs and thoughts turned to adopting the world brand leader, the American Pressurised Water Reactor – PWR – for the third generation. Towards the end of the decade, when the first Thatcher Government was elected, there was still the hope of an expanding nuclear industry. Yet the prospect of a new power station a year for ten years never materialised. Only one new station has been built, Sizewell B, whilst some of the Magnox reactors have been closed.

Environmental pressure groups and incidents such as Three Mile Island and Chernobyl turned public opinion against the industry. More devastating in the longer term was that market forces held sway against strategic long-term energy planning. As the expansion of the industry slowed dramatically so did the flow of government money into it and consequently into academic research. The universities reacted to the changes on the pragmatic basis of supply and demand. With neither significant demand nor financial support from the industry and decreasing popularity amongst students, nuclear-related courses were replaced by those pertinent to other industries where there was a demand.

The number of university staff carrying out nuclear research, expressed as a percentage of the total number of chemistry staff, dropped ten-fold between 1960 and 1990 resulting in the closure of key facilities. From the halcyon days of the fifties and sixties there is now a general air of doom and gloom that the topic is populated by a declining number of academics reflecting on better days and that little new blood is coming through. Expertise and competence in the core nuclear technologies are increasingly difficult to sustain and there are fewer academics capable of speaking informedly about, or raising the profile of, an industry that is now regarded as a pariah by many.

Let me now deal with the present UK situation in a little more detail.

I find it amazing that there are no longer any nuclear specific undergraduate courses left in the UK. Yet, on paper, the number of undergraduates reported as having a nuclear content in their university education has remained at least constant and has possibly even increased over the last decade The paradox is explained by the extent of the courses which claim to contain a nuclear component. Whilst this is difficult to quantify, it seems that this has declined with time and it is unlikely that any undergraduate programme in the UK could now claim any appreciable nuclear content. Thus despite apparently healthy numbers, it seems that the knowledge pool in nuclear sciences is decreasing at the undergraduate level. Further, because even though the student population has increased in the last decade, the percentage of students studying nuclear sciences, to any extent, has fallen.

Although at the masters and doctorate levels, the number of students pursuing nuclear courses has slightly increased over the last decade, which is encouraging since masters programmes are where the main specialisation into disciplines of relevance to the nuclear industry is focused. Nevertheless, there is a dark cloud associated with this ray of sunshine. Research council funding, in effect government funding, for post-graduate work in the nuclear area is getting steadily more difficult to obtain. If the viability of some post-graduate activity became critical, it could disappear very quickly. There would then be a knock-on effect in that associated elements of some undergraduate courses would also cease because the undergraduate courses are only sustained by the availability of key academics with postgraduate funding.

Whilst one university introduced a new masters programme in Radiometrics, together with a new Radio-chemistry training laboratory, and another introduced an undergraduate module on Nuclear Radiation Chemistry, other universities have witnessed cutbacks in recent years. Indeed, the overall trend is for universities to reduce, or even cease, their support for nuclear related courses. This is linked to the consolidation of the industry as it focuses on operating existing plant and power stations more efficiently rather than on building new plant and stations. However, through their promotional efforts, by maintaining close links with the industry and by broadening the content of their courses to appeal to a wider audience, several universities have managed to maintain their position against the trend.

Apart from nuclear programmes there are certain non-nuclear programmes which provide good quality, although non-specialised, graduates and post-graduates for the industry. A number of research areas provide PhDs or post-doctoral fellows for the more challenging aspects of nuclear R&D such as Materials Science, Metallurgy, Ceramics etc. The numbers graduating in engineering subjects (Civil, Mechanical etc) has remained relatively constant whilst the number of post-graduates has sizeably increased. Taken overall, there is a substantial number of well-qualified engineers emanating from British universities and available, therefore, to the nuclear industry. The only problem is that the industry then has first to attract them and then has to train them. But I'll touch on that in few minutes.

Whilst the reduction in university staff involved in teaching nuclear subjects has not been so dramatic over the last decade as we saw it was in previous decades, it still continues. Worryingly, there is a significant peak in the 50-60 age bracket, with nearly as many in this bracket and above as there are below the age of 50. The usual age for retirement is 65 and so I believe we are heading for a crisis in the next few years.

If the staff are not getting any younger, then neither are the facilities. Whilst most of the facilities in universities are over 30 years old, most will be available for the foreseeable future. These include radio-chemistry laboratories, radiation measuring laboratories, a cyclotron, a dynamitron and radioecology facilities. However, hot cell facilities are only available in two universities and both facilities are likely to close around 2000. Britain now has only one research reactor at Imperial College, which is expected to last until at least 2010.

Details of the employment destinations of students who have taken a nuclear course are difficult to get hold of and less than complete. Nevertheless, what data exist paint an encouraging picture of a high percentage of the students from the masters programmes entering the industry, as did at least half of those who pursued doctoral programmes. This contrasts with data for graduates from nuclear related courses that show little more than one tenth entering the industry. However, the graduate population is an order of magnitude higher than the post-graduate population. In any event, supply is regulated by demand from the industry. With no design development and the industry contracting and becoming ever cost conscious, recruitment is currently at a low level. Arguably therefore the current state of the Industry itself is a key factor in the potential lack of essential core skills in years to come.

Furthermore, it is all right having the right numbers in the right disciplines entering the industry, but what of quality? Historically the nuclear industry commanded the best brains because it offered the best resources and facilities and enjoyed the privilege of being at the cutting edge of technical development. Now the perception of many potential graduates to the industry is negative. They do not see the industry as being at the forefront of technical innovation but more as a dinosaur. Not surprisingly, concerns are beginning to be voiced by some in the industry about the availability of appropriately qualified people. I think you can tell where I stand. I am worried about the long term availability of talented, appropriately trained people who will form the bedrock of our Industry in years to come.

Of course, people are not just going to beat a path to our door. We have to entice them in. And it is fair to say that the recruitment efforts made by the UK industry, BNFL included, have so far followed what might be called traditional patterns. That is to say, the principal mechanisms for attracting young people have been good salaries and working conditions and the prospects for secure employment. In my view we need to be more pro-active, we need to go out and court the best graduates, and we need to bolster key areas of skills and if necessary facilities. At BNFL we are now beginning to do this and I'll talk about how in a few minutes.

Once employed people need training. At BNFL, like the other UK nuclear companies, training is designed for both new graduates and experienced staff with the aim of increasing the competence of the trainees in their specific function within the Company as well as supporting continuous professional development. Here we are no different from any wise, well established Company with one key exception. Whilst it is true that a wide range of courses is being operated with a strong focus on individual company needs, much training is in response to regulatory requirements. And here is another emerging concern. The age structure of the trainers shows a peak at 40-50 years. Whilst it is logical that experienced staff be used as trainers, it must not be forgotten that, with early retirement schemes operating in many organisations, a considerable number of these trainers are likely to retire over the next few years. Whilst young trainers are coming through, the numbers are not as great as those that will be leaving. Given the university situation, the provision of suitable trainers in the near future could well be a matter of concern.

Nuclear education is not yet at crisis point in the UK but it is certainly under stress. It is true that the necessary specialist skills in areas such as radiation protection and radiochemistry are currently being maintained at adequate levels, primarily by diversifying the customer base for such activities in the universities. But where diversification is not possible, courses and research have ceased as the industry has become more cost conscious and more targeted in its requirements. The notable exception is safety research, considered essential by the industry and the regulator, where it is absolutely vital the partnership evolved over many years continues and begins to embrace the concerns relating to the academic and national research capability.

The needs of the industry, both in terms of recruitment and research, have declined as it has reached maturity and as it seeks to be more competitive in a deregulated energy sector. No new power stations are being built and none planned for the foreseeable future. In this context it is I suppose not unexpected on a straight supply and demand basis that nuclear education should have declined. However, it is crucial that the area of nuclear education is sufficiently robust and flexible to support the industry as it evolves. The concern is that the decline in nuclear education is such that it may not be able to do this.

At BNFL we are trying to combat that concern in a number of ways and at a number of levels.

In the UK, the number of youngsters studying science and technology beyond the age of 16 is worryingly low. For physics and chemistry, the percentage has been going steadily down for a number of years. That the overall numbers may have increased is small comfort – the message seems to be that science, technology and engineering are not highly regarded as occupations. Obviously these opinions form at an early age. For the last ten years BNFL has offered teaching resource materials in science and technology to help teachers deliver those parts of the National Curriculum. The resources do not necessarily dwell on or even deal with matters nuclear because there is little scope to do so within our National Curriculum. Instead we have tried to promote science and technology as interesting and exciting subjects for the age range 5-18. Where possible we have used examples from the nuclear industry but we have not contrived to do so. The materials are written by teachers and produced by companies outside BNFL that are experienced in this area. To add value, we sell the resources but at a greatly subsidised price. We have managed to achieve that delicate balance of providing teachers with products at a price they can afford and at a cost we can endure for a long period.

Through our Corporate Communications Department, we also work with other organisations to support as many events promoting science to young people as we possibly can within the inevitable budgetary constraints.

At Sellafield we have a £5M Visitors Centre explaining the nuclear fuel cycle in an informative an entertaining way. This can be combined with a coach trip around the site. Both are free and over hundred thousand visitors a year come to see us. In addition we offer conducted tours round all of our sites and it is encouraging that school parties make up a sizeable percentage of those visiting. We have school liaison officers at all of our sites who regularly visit schools local to the sites. The traffic is not all one-way as the teachers also come onto to the sites. Wherever possible, we donate surplus equipment to local schools. Many of our key scientists and engineers on a voluntary basis regularly give talks to schools about the nuclear industry and the excitement they feel working within it. We try to encourage our younger scientists and engineers also to do this sort of outreach work.

At the university level, we sponsor or co-sponsor about 30 PhD students a year. Overall we have about 100 contracts with about 35 universities, mainly in the UK, which makes for annual commitment of around £3M. In the past we have concentrated very much on the technical aspects of the work. We have been more interested in results than people. We are changing that. We are now looking more carefully at the students we sponsor as possible recruits into the Company. We are talking more to academic staff that we know about recruitment.

A few minutes ago I referred to the fact that we are going to be more proactive in our recruiting. For the first time we have just appointed someone, a single person not a disparate group of people, who is responsible for the recruiting needs of the whole of the BNFL group. We intend to use our existing links with universities more pro-actively. We also be establishing long-term links with universities through named individuals. These will be young people in BNFL who will liase with the university that they graduated from not that long ago. They will still know their way round and know the academic staff. They will have a small budget to put up prizes for the best piece of research, the best speech etc. The idea is to keep the profile of BNFL and the nuclear industry high in the university – whether we are wishing to recruit that year or not. This person will act as a conduit between BNFL and the university so that the university is kept informed about BNFL as it evolves and vice versa. Like most things in life, this idea is not new. It has worked well for other companies so we see no need why it should not work well for us.

We are also looking at how we manage our university contracts. Traditionally we have managed them on an individual basis as part of planned and budgeted programmes of work. We have installed a combined data-base and purchasing tool so that we have complete accountability and transparency and, importantly, we can now manage our contracts as one would a portfolio investment. We noticed that clustering our contracts, which was happening to some extent purely by chance, and working with fewer universities might be a better way of doing things.

The approach offers mutual benefits. Above all the contracts are designed to be long term, which will give the time, often lacking in one-off contracts, to develop trust and understanding of each other's cultures and priorities. Suddenly research planning, accessibility to research funding, staff recruitment and the like start to blossom and thorny little problems like IPR and overheads wither on the vine.

One area of particular concern for us was the decline of radiochemistry research in the UK. This is part of our core activities as a company and it is pretty essential to just about everything we do. We decided to re-establish a Centre of Excellence in the UK and after a process of assessment over the last year, we have established a Centre of Excellence in Radiochemistry in the Chemistry Department of Manchester University. The Agreement has just been signed whereby BNFL will invest £2M over 5 years in research staff and studentships. The university will be refurbishing a suite of laboratories, establishing a professorial chair, two lectureships and ensuring the security of the centre beyond the initial five year period. The Centre will be an international hub for those working in radiochemistry, whether in industry or academia. It will not only give us the knowledge we need but will also ensure that radiochemistry, currently in terminal decline in British universities, will be re-established. Two new lecturers and 5 PhD students have just been appointed for the academic year starting in October. We are looking to do something similar in other areas such as non-destructive testing and powder technology.

We lend support to universities whenever we can, whether it be student placements or providing lecturers. This year, for example, we are providing lecturing cover for the two nuclear MSc courses at Birmingham University so that the course director, David Weaver whom I know is known to many of you here and who is probably somewhere in the audience, can have a sabbatical. A sabbatical that he intends to spend up-dating the course material and producing remote learning packages – both extremely valuable endeavours.

Like many organisations, a number of our senior research scientists are well respected in their fields of expertise and have visiting professorships at various UK universities. This is something we encourage and will back enthusiastically as a Company.

Through the trade association, the British Industry Nuclear Forum, BNIF, we are a member of NAILS. This hideous acronym stands for Nuclear Academics Industry Liaison Society Seminar. As its name implies, it consists of academics who have an interest in nuclear matters and representatives from the industry. The group meets 2 or 3 times a year and it is an excellent way of exchanging information and sharing good practice.

In the earlier part of my talk I briefly mentioned safety research. As we all appreciate, this is of paramount importance. Not only from a purely regulatory point of view but also to demonstrate unequivocally to the government and the public our "licence to operate". We work with other companies in the nuclear industry and with the regulator on jointly funded research collaborations. The Industry Management Committee (IMC) programme is a collaboration led by British Energy and BNFL, amongst others, which sponsors the maintenance of research capability to underpin the continued operation of BNFL's ageing Magnox reactors. This research capability rests in a range of key teams both within the industry and UK Universities. Very similar skills are required to support British Energy's AGR's; the programme is therefore an efficient way to deal with the needs of the industry. Also by ensuring the projects are aimed at solving issues which are of interest to HSE, many of their research needs are met.

I also mentioned earlier BNFL's community involvement through supporting science teaching in schools. On a much bigger and ambitious community scale, BNFL is also a founding father of an organisation called Westlakes Research Limited sited in West Cumbria, which has the bold aim to develop higher education and bring a technology led regeneration to the region. Westlakes, which consists so far of a scientific consultancy company employing 70+ technical staff and an International Postgraduate Centre, specialises in the areas of environmental science, biotechnology and genetics and epidemiology. Through its success, and the special partnership between BNFL and the regional development agencies in helping it happen, Westlakes will help BNFL build and protect some of its important technical competences. But above and beyond this, as I've just said a moment ago, Westlakes will also be the vehicle to develop higher education and bring about a technology led regeneration this beautifully scenic, but admittedly remote, part of West Cumbria.

As BNFL's business is becoming more global, so it becomes more practical, indeed essential, that we look beyond the constraints of the UK coastline to identify our research partners and collaborators. It is equally important that we use these links to promote awareness of nuclear research and to encourage new blood into the industry.

BNFL's international research activities have focused on the establishment of relationships to support the Company's business objectives, such as our ongoing collaboration with organisations in Canada and Korea for the use of recycled uranium fuels in CANDU reactors. Similarly we have ongoing collaborative work on fast reactor fuel cycles, notably with researchers from Japan and France, underlying BNFL's commitment to the fast reactor concept and the long-term responsible utilisation of our energy resources. We also have collaborations with Japanese and Russian research organisations for the development of reprocessing and MOX technology, and we maintain technical interactions with national and international groups that develop relationships of importance and influence to BNFL, such as the European Commission 5th Framework Programme and the activities of the IAEA and OECD/NEA.

Across all of these networks, including the portfolio of links to US universities and National Laboratories we inherited with the acquisition of Westinghouse, we will seek to deliver quality research work into BNFL, whilst pursuing opportunities to promote the teaching of nuclear technology and the maintenance of key international facilities.

This is typified by our input to the highly respected Frederic Joliot – Otto Hahn Summer School at Cadarache and Karlsruhe – a truly excellent initiative. I hope that this approach can be extended and will be the blueprint for similar initiatives in a wide range of countries in the future, as I'm sure that international links between industry and academia offer a major opportunity to develop nuclear education on an international basis.

I hope what I've shared with you this afternoon gives you an insight into the way BNFL is reacting to the challenges that we face. Challenges that I suspect are common to many us.

I believe that it is absolutely essential that we maintain nuclear education.

While training can provide good personnel for daily operation of nuclear facilities, research and development needs graduates well educated both in depth and in breadth from nuclear programmes.

We, the industry, need to retain the present level of expertise so that future generations may consider the role of nuclear power as part of a balanced energy mix that will reduce CO_2 levels and preserve fossil resources.

We must also look outwards and consider those countries that do not yet have nuclear power but aspire to do so. When the developing world moves to exploit nuclear technology, we must make sure that we have access and the necessary influence to ensure that it is done in the appropriate manner with regard to global issues such as safety, environment, waste management and non-proliferation.

There is also the legacy of our own nuclear past to consider. No matter what ones feelings about nuclear power may be, there are many important current and long-term future problems that will require significant expertise, independent of the future of nuclear power. Perhaps this could be the way to attract talented young people into the industry. We certainly need them because the current expert community is ageing and assuring continuity of knowledge will be increasingly difficult without them.

Human resources do not appear instantly – it takes a minimum of 4-5 years to train someone coming into higher education. If the present trends and their consequences are to be averted, an investment in nuclear education needs to be made NOW. Individual countries may face shortfalls but the combined expertise and resources present at this conference are still sufficient to support the needs of the industry as it evolves. During the course of this conference let us take the opportunity to see how we might do that.

It is clear that only by working together in partnership: nation to nation, industry with academia, industry with the regulator, that we have a chance of reversing what otherwise must be a very worrying trend for us all. We can no longer expect governments to sustain our generic requirements. We must be prepared to work together proactively to deliver what we need for the future.

THE NUCLEAR INDUSTRY AND THE YOUNG GENERATION

A. Hanti
ENS Young Generation Network
Nuclear Power Plant Paks
P.O. Box 71, H-7031 Paks
Hungary
szaboag@npp.hu

It is a great honour for me to have this opportunity to speak to you on the occasion of this workshop ensuring competence into the 21st century. Certainly, in no other industrial branch the gap between generations of employees is so large as in the nuclear industry. Therefore I consider this to be a compliment to the work accomplished by young engineers and scientists of the YGN throughout Europe over the past years. Thank you very much for this special sign of appreciation.

As I know, the Committee on Nuclear Regulatory Activities made a report on future challenges. This report recognized a range of factors including the aging expertise of people in the industry, the changed external environment, the need for retention of corporate knowledge in quality organisations and how to match future competence from current resources.

It is a specific challenge for the young generation to fight for nuclear energy and to give it a position of equality with other energy sources; a position that it should get in view of the global debate on protecting our climate and conserving natural resources. This work was started in Kyoto at the 3rd Conference of the Parties to the United Nations Framework Convention on Climate Change and was pursued even more intensively during the 4th COP in Buenos Aires. But we can only reach our goal if there is a strong synergy between the generations – a synergy in which know-how and experience is combined with fighting spirit and openness. Only then we can pursue new paths together and motivate today's young people - and only then we can shape the image of a high-tech industry full of promise for the future.

Let me introduce you our organisation in a few words. The European Nuclear Society was founded in 1975. It is a federation of 25 nuclear societies from 24 countries – stretching from the Atlantic to the Urals and on across Russia to the Pacific. Through Russia’s membership in the Pacific Nuclear Council, ENS is directly linked to that area, too.

ENS comprises more than 20 000 professionals from industry, power stations, research centers and authorities, working to advance nuclear energy.

ENS has three Associate Member Societies in Australia, Israel and Morocco. Also it has collaboration agreements with the American Nuclear Society, the Argentinean Nuclear Energy Association, the Canadian and the Chinese Nuclear Societies.

Within Europe its activities are co-ordinated with and complementary to those of Foratom.

So, while ENS concentrates its efforts within its European federation, it is also networking with partners world-wide.

ENS is doing pioneering work with its Young Generation Network, standing for positive measures to recruit and educate young people as engineers, technicians and skilled staff in the nuclear field: from school to university and in the industry.

In 1995, the late Mr. Jan Runermark, aware of the fact that the pioneers of the Nuclear Industry start to retire, looks for a way to ensure the exchange of knowledge from the older to the younger generation. The enthusiasm of the nuclear beginnings had decreased and young people were not attracted to this field any more. A Young Generation Network was created within Europe. The network is affiliated to the European Nuclear Society and to the national societies promoting nuclear technology. The ENS YGN is composed of representatives from each national YG (one per country). The Network members meet at least twice a year. The Network elects its own chairperson any two years. The chairperson or appointed deputy, respectively, has a seat on the ENS Steering Committee.

The goals of the YGN are:

- to promote the establishment of national Young Generation networks;
- to promote the exchange of knowledge between older and younger generations cross-linked all over Europe;
- to encourage young people in nuclear technology to provide a resource for the future;
- to communicate nuclear issues to the public (general public, media, politicians).

The priorities of the YGN are:

- Know-how-transfer: participating in Nuclear Conferences;
- Training and Education (VVER-1000 courses held at Temelin, EPR-course, mission to Russia);
- Public Perception and Communication with the Public (YGN Positionpaper, Round Table Discussion, Media Contacts);
- Potential Role of Nuclear in the Climate Change Debate (COPs, SBI and SBSTA meetings). Though the YGN was formed only in 1995, it has already established networks in 21 countries.

The YGN has a position paper: “On the Future Need of Nuclear Energy”. Environmental protection has a young, progressive image, while nuclear technology has an old, conservative image. It can be very refreshing to have young people telling why nuclear power is an important factor in their view for the future.

As young people and scientists we are today faced with an extreme conflict situation between: an emotionless, matter-of-course attitude toward technology, as we have been educated to adopt, and a social environment which is shaped by the protest movements of the 1968 generation, who today rule politics and the economy.

The factual attitude adopted by our generation to nuclear energy as an environmentally friendly, economical and promising leading-edge technology – in particular with a view to the protection of our climate and the conservation of natural resources – is in conflict with the oft-publicized ideologies involving concepts for abandonment of nuclear power, ideologies which arouse controversial discussion and which we have often refuted.

Important positions of power and decision-making are occupied by persons who block decision-making processes or impede key innovations by canceling funds for R&D. Such obstruction is based on these old ideas or an unwillingness to accept risk together with shortsightedness on long-term developments.

Many of the former nuclear energy activists who still have good ideas or believe in future concepts, have been worn down by the years of debate or have already retired.

Is the only option remaining today to keep quiet and wait until economic pressure increases to such an extent that thinking in terms of solutions is once again in demand?

To inherit what our fathers achieved, we must have the opportunity to opt for what is correct and reasonable, free from any external constraints.

Choice of profession is subject to fashion trends.

However, decisions now being made in energy policy define the environment we live in and the quality of life of our children for the next 50 years - which is about equal to the working life of a nuclear power plant, or ten parliamentary terms.

Nuclear technology should therefore not be buried like a dinosaur as the plaything of political and economic ideologists. To do so greatly risks missing out on know-how transfer in a technology that already meets 17% of the power demand worldwide.

However, past mistakes need not be repeated if we, the young scientists and engineers, make the knowledge of the experts our own and continue to develop it jointly in well-understood accord between generations.

What can industry do for young people?

The most important thing is to impart accurate and essential knowledge, to promote the correct training programmes and to maintain motivating projects.

And promising projects like e. g. the EPR should not be scrapped by those responsible for financing who, fearing the liberalization of the energy markets and thinking short-term, prefer to bank on low-cost combined-cycle power plants and currently cheap gas, rather than making large-scale profitable investments over decades.

Ongoing lack of large projects for new NPPs means the industry is losing direct, personal experience of commissioning as people retire or quit. Such know-how exists increasingly only on paper. Hence nuclear energy’s potentials for the first half of next century are being overlooked.

Further ahead, the fusion reactor will perhaps not become reality for another fifty years, but is also an option for the future. It should not be dropped due to lack of current need only to be started again later.

The challenge is not only to achieve and optimize standards, but also to seek and tread new paths.

What can we young people do?

We can convince the older generations to reflect less about the past and more about the future.

With new methods and new media we should jointly address the general public and above all young people, motivate them and support them in developing new ideas and tapping experience.

Through our public commitment for nuclear energy, we as the coming responsible generation can competently and convincingly shape the image of a young, promising high technology. We want to achieve this without being aggressive or defensive and without overtaxing the general public with facts and figures, but while empathizing with people's needs and fears.

We accept the challenge of wanting to shape our future ourselves by taking possession of the inheritance from our fathers and carrying it responsibly into the future.

Our nuclear community is presently challenged by a number of issues which are of critical importance for the future of our industry.

Clear and present examples are:

- The liberalisation of the electricity market (competitiveness).
- The announced plans for a nuclear phase out in several countries of the European community, and …
- The role of nuclear energy in the debate on climate change.

The nuclear industry is taking these issues very seriously because they will – in one way or the other – affect its future development.

But …, ladies and gentleman … as we speak about the future of the nuclear industry, there is another issue which usually gets much less attention ... but which might … in the end … become equally as important.

I am referring to the issue of "know-how transfer".

Passing on the knowledge base of our industry from the present generation to the next generation AND further …

Highly qualified and motivated people have brought our industry were it stands today – an advanced, safe, clean and reliable source of base load energy at competitive cost.

A pre-condition to continue and build on what has been reached so far is again the availability of highly qualified and motivated people.

But, …where are we standing now ?

- the age profile of employees in the nuclear industry continues to rise;
- the educational infrastructure shows clear signs of erosion;
- persistent public scepticism and political opposition discourages young people to start an education or career in the nuclear field;
- … and … for those who did – only very few have been able to gain experience in the design, engineering, construction and commissioning of new nuclear power plants.

Young people in our industry share the same dedication and passion for nuclear technology with previous generations. The circumstances however, seem to be a lot less promising as they were 20-30 years ago.

The aims are to:

- raise the level of awareness for this issue; … and,
- exchange experiences, opinions and suggestions on how the industry could deal with the issue.

It is recognised that we have to look at this issue from two different angles:

First the mechanism itself: How do we pass on the nuclear knowledge base from the present generation to the next generation. And second: How do we make sure that there will be a young generation to pass on this knowledge to. In fact: two sides of the same coin.

Attracting young people to the nuclear industry starts before students choose an education or career path.

Lack of research funds and low enrolment is going to force universities to drop nuclear studies. Besides,.... many universities have only one staff member for nuclear studies.

Already, the supply of well trained engineers and scientists is starting to dry up.

You can only imagine how will nuclear operators, regulatory bodies and the industry recruit the talent needed to run and service existing plants, or if necessary, to close them down and decontaminate the sites.

The little interest among students for nuclear might be caused by:

- a general tendency that technical studies are getting less popular, in favour of social sciences, business;
- the rather conservative image of our industry;
- low expectations with regard to job and career opportunities – and this has everything to do with public perception influenced by: negative publicity in the media, lack of new construction projects, governments who fail to take a clear position regarding to nuclear;

- and also, WE, young people in nuclear, noticed that other young people often have no clue about what is going on in the nuclear sector and how fascinating and interesting the work can be.

What makes the problem more acute is that the nuclear industry has already effectively skipped over a generation. The industry boomed in the 1970s, when many reactors were being built.

Since the mid 1980s demand slowed and hiring of new people stopped. As a result the demographic curve of the industry shows a disproportionate number of people over age 55 – a considerable gap representing what sometimes is called the lost generation of 35-55 year olds.

This fact makes it even more important that the pioneers in our sector pass on their knowledge and expertise to the young generation before they retire.

Fortunately this need has already been recognised by several companies.

Know-how transfer is an issue that needs to be taken very seriously if we want to preserve the knowledge base of the industry.

The question remains whether the industry as a whole will be able to ensure that future demand and supply for qualified manpower will be in balance.

I would like to conclude with some of the suggestions and remarks which could be worthwhile for the industry to consider when dealing with this issue:

- What can we do to attract more students to the universities for a nuclear education and subsequently to our industry?

Our well developed Public Relations and Information departments could start focusing their attention not only on politicians, the media and the general public, BUT ALSO on polishing the image of the nuclear industry at universities and high schools.

In addition … We need to convincingly demonstrate that our industry provides excellent job and career opportunities. With support of our companies the Young Generation could play here a major role.

In parallel … we need to demonstrate that our sector has a future.

We have enough politicians and journalists who like us to believe otherwise.

Therefore, we need a firm and unconditional commitment to nuclear power from the senior management of the Utilities, the Power plants and the Industry.

Let their be no doubts or misunderstanding from our side.

And … in order to reconstitute the educational infrastructure or at the least stop further weakening … Utilities, Power plants and other sectors of the Industry could consider to actively support the universities by facilitating co-operation and exchange of know-how and experience.

Know how transfer is a challenging issue for the nuclear industry that needs to be taken seriously.

Actually, I see my presence up here today – as a representative of the young generation – as being a positive sign, and I am sure that all of you agree when I say that the transfer of know-how from one generation to the next is an essential precondition for any continued use of nuclear energy in the future! We have to make sure that if there is a demand – and this limited period of time is clearly estimable, especially in view of CO_2 emissions – the adequate know-how for something like licensing procedures or the accompanying infrastructure will still exist. This is the only way in which we will have any chance of assuring continuity in the further advancement of this “high-tech” sector of industry. So, let me now ask you how serious the decision makers in politics and industry are when they talk about the need to prevent essential know-how being lost forever when the older generation retires?

To prevent a break in continuity, experience and knowledge cannot exist on paper only – in the future not either – but important educational programmes and motivating projects must be maintained.

My education as well as my belief in common sense and fairness led me to the conviction that I have a personal obligation – and indeed a desire – to take responsibility in shaping the role that nuclear energy can and should play in the future as part of a sensible mix of energy sources. In order to guarantee that your and my children will be able to enjoy a certain quality of life in times to come, every possible opportunity should be taken to ensure that they will be free to choose what is right and reasonable. For who really knows what the future will bring? Nothing is as uncertain as political studies and narrow-minded energy scenarios!

For the future, the threat of global warming is widely expected to present nuclear with a window of opportunity, and the industry is to be applauded for raising a collective voice at the climate change conferences.

It must be obvious to governments that nuclear can be an important part of the solution to global warming, even though, for the moment at least, they feel unable to acknowledge its potential role.

From its encouragingly firm base, the nuclear industry must work out its own salvation by operating plants safely, by retaining a competitive edge, by continuing to maintain the highest possible standards and by ensuring that the environmental benefits of the technology are clearly conveyed to the outside world.

MANAGING NUCLEAR SAFETY RESEARCH FACILITIES AND CAPABILITIES IN A CHANGING NUCLEAR INDUSTRY: THE CONTRIBUTION OF THE OECD/NEA

Jacques Royen
OECD Nuclear Energy Agency
Le Seine Saint-Germain
12 Boulevard des Iles
F-92130 Issy-les-Moulineaux
jacques.royen@oecd.org

Abstract

Although the safety level of nuclear power plants in OECD countries is very satisfactory and the technologies basic to the resolution of safety issues have advanced considerably, continued nuclear safety research work is necessary to address many of the residual concerns, and it remains an important element in ensuring the safe operation of nuclear power plants. However, the funding levels of national Government safety research programmes have been reduced over recent years. There is concern about the ability of OECD Member countries to sustain an adequate level of nuclear safety research capability. The OECD/NEA has a key role to play in organising reflection and exchange of information on the most efficient use of available technical resources, and in the international management of nuclear safety research facilities and capabilities in a changing nuclear industry. Possible initiatives are mentioned in the paper.

1. The continuing need for nuclear safety research

The aim of nuclear safety research is to provide information to plant designers, operators and regulators in support of the resolution of safety issues, and also to anticipate problems of potential significance. Better understanding of phenomena that have an influence on reactor safety has been one of the major contributors to the improved assurance of nuclear safety. Over the past thirty years, significant amounts of money have been spent in the field of nuclear safety research, advances have been made in many areas and there is now better understanding of problems, phenomena and processes. In particular, research results have been integrated into computer codes, major codes have been validated and our ability to predict the way things happen, e.g. power plant transients, has been transformed over that period. Progress in reactor safety has been substantial, safety improvements have been introduced and safety margins are now quantified with increased confidence.

NEA and its Committees have a central role to play in ensuring international co-operation and providing authoritative advice in the field of nuclear safety and regulation. The NEA Committee on the Safety of Nuclear Installations (CSNI), which is an international committee made up of senior scientists and engineers, with broad responsibilities for regulation, safety technology and research programmes, reviews the nuclear safety research performed within OECD countries, encourages in-depth exchanges of information, data and experience, develops common technical positions on important safety issues, promotes joint projects, discusses the future direction of safety research, and identifies areas of agreement and areas for further action. CSNI, in collaboration with the Committee on Nuclear Regulatory Activities (CNRA), provides the meeting ground for in-depth exchange of information on reactor safety research and on reactor operations and regulation for the most advanced countries in this technology.

Although the safety level of nuclear power plants in OECD countries is very satisfactory and the technologies basic to the resolution of safety issues have advanced considerably, there is an opinion broadly shared throughout the international nuclear safety community that there is the potential for yet further improvement. Although the range of uncertainties is limited, continued nuclear safety research work is necessary to address many of the residual concerns, and it remains an important element in ensuring the safe operation of nuclear power plants. Operating experience, plant ageing, emerging technologies and new design concepts lead to a requirement for additional research to be undertaken. Also, Government Agencies need to ensure that research is undertaken to maintain essential technical national expertise and capabilities so that both operators and regulators can meet their respective responsibilities.

There is need to continue to invest in safety research in the future in order to develop understanding and to maintain our capability and expertise, as well as to be able to address emerging safety issues. Further discussion is needed in a number of safety research areas. Moreover, increasingly strict licensing requirements, and licensing of new reactor designs, have stimulated the need for further confirmatory research; these requirements are likely to become even more demanding in the future.

2. Concern about the decreasing level of nuclear safety research resources

In the field of nuclear power safety, OECD countries' Government Agencies have broadly similar responsibilities. They need to undertake, fund or sponsor research – or Governments must ensure funds are available – to develop and maintain technical national expertise so as to establish their own position on safety matters and enable them to meet their obligations. However, in most

Member countries, the funding levels of national Government safety research programmes have been reduced over recent years.

In a Collective Opinion Statement published in 1996, the CSNI expressed concern about the ability of the OECD Member countries to sustain an adequate level of nuclear safety research capability individually, and potentially collectively, even though there was an international consensus in almost all technical areas on research needs and objectives.

Care is needed that the observed trend of decreasing nuclear safety research budgets does not have an adverse impact on the ability of Government Agencies to fulfil their safety responsibilities, especially since the reduction in Government direct or imposed funding of nuclear safety research may not have been offset, in many cases, by increases in the funding of safety research programmes of reactor vendors and operators.

Forming an independent regulatory position might be in jeopardy in some cases. If a significant problem occurred over the next ten years, there might not be in some cases sufficient knowledge and capability to deal with it in a timely manner if the current trend continues.

Moreover, the changes associated with electricity market deregulation and restructuring of the electric utility industry have operational and economic consequences that may have a strong impact on the maintenance of safety research capabilities and facilities; for instance, the privatisation of nuclear utilities has led to massive reductions of staff, many of whom were in research posts. Nuclear regulatory authorities have expressed their concern about this situation and said that, in some cases, staff reductions had caused shortages in vital expertise. Major regulatory challenges arising from government policies to liberalise energy sectors have been identified by the CNRA in a report published in 1998 (1). The perceived challenges are multiple, ranging from technical issues to socio-economic and political issues; organisational, management and human aspects; and international issues. This work has been summarised in the first paper presented in the Introductory Session of the Workshop.

For safety authorities, the first challenge is to ensure that, as the business environment changes, economic pressures do not erode nuclear safety. It is fundamentally important, though, that the nuclear industry recognises that there are no economic shortcuts to safely operated, economically viable nuclear generation, and that nuclear electricity generators must continue to maintain high safety standards, with sufficient attention and resources devoted to nuclear operations and safety research. A related aspect is that there is increasing need to maintain and promote nuclear safety culture, in particular at all levels of utility personnel including higher management, and with pressure for greater openness, to interface more effectively with the public, media and parliaments. This also means that the human element is one of the most critical aspects of ensuring safety.

Quality organisations require well educated, well trained and well motivated staff. The availability of higher education courses in nuclear engineering is declining in many countries with nuclear industries. If this continues, where will future nuclear engineers receive their grounding in the subject? How will the industry and regulators continue to attract high-calibre, qualified recruits? OECD/NEA is engaged in a survey and analysis of education in the nuclear field, with a view to encouraging discussion on the infrastructure needed for the use of nuclear energy (2). This work is described in the second paper presented in this session.

CSNI has expressed strong concern that dwindling resources and support as well as stagnant nuclear programmes may lead to untimely shutdown of essential large experimental facilities and the breaking up of experienced research and analytical teams with the consequent loss of competence and reduced capability to deal quickly and efficiently with future safety problems. Unavailability of large research facilities will make more difficult the understanding of complex thermal-hydraulic and severe accident phenomena, the verification and validation of computer codes, the clarification of uncertainties, and the demonstration of the robustness of severe accident management strategies. It will contribute to reduce the capability available to adequately regulate and support operating reactors. It will undermine the confidence to be put in future reactor designs. It will hamper advanced training of engineers and scientists. The CSNI has stressed that maintaining adequate levels of expertise would be one of the key issues of future nuclear power development.

3. The role of the CSNI group of senior experts on nuclear safety research facilities and programmes (SESAR/FAP)

The CSNI has decided to ask its Group of Senior Experts on Safety Research (SESAR) to investigate the implications of the decrease in the level of nuclear safety research funding and of the untimely shutdown of essential research facilities and capabilities, and to propose possible remedies This group has been in operation since 1991; its initial main task was to review the current situation in Member countries in regard to nuclear safety research, to reflect on a rationale for safety research in the years to come, to identify future needs, and to establish a priority list. A first report, "Nuclear Safety Research in OECD Countries", was published in 1994 (3), a second one, "Nuclear Safety Research in OECD Countries: Areas of Agreement, Areas for Further Action, Increasing Need for Collaboration" in 1996 (4). Given that the earlier studies had laid out where research priorities should be focused and that there was a general consensus on this, the concerns over the availability of both capabilities and facilities able to perform the work prompted the CSNI to commission a third report, "Nuclear Safety Research in OECD Countries: Capabilities and Facilities", published in 1997 (5).

Work done in recent years by SESAR and its successive metamorphoses (currently, SESAR/FAP) has addressed the ability of current safety research programmes to meet identified needs. It was concluded that, in general terms, technical programmes and facilities existed, or were planned, which would meet the majority of the research needs identified for the short term (the next few years), although, in most areas, some additional effort appeared to be justified and the needs were clarified. Longer-term needs were identified against three basic assumptions: (i) improving safety and operational performance of existing plants; (ii) life extension of existing plants; and (iii) development of new designs. Several criteria had to be met in order to justify a long-term programme; the main points were:

- is the capability or facility* necessary for any of the three requirements identified above?
- is the capability or facility unique to the nuclear industry?
- if lost, is the capability or facility expensive and time consuming to replace?

Based on these criteria, long term research needs were identified in seven technical areas: thermal-hydraulics, fuel and reactor physics, severe accidents, human factors, plant and control monitoring, integrity of equipment and structures, and risk assessment. Recommendations were developed concerning general strategies that could be utilised by Member countries to maintain capability and select facilities. Co-operative (international) programmes were considered a key element of the response to long-term safety research needs.

***** "capability" refers to the ability to perform a given task – it implies expertise and access to specialised equipment; "facility" refers to semi-permanent installations, including also analytical equipment.

Concern has been expressed, however, about the long-term availability of several capabilities and facilities important for providing information that will be needed by the international safety community during the coming decade. It seems logical to investigate the possibility of operating the facilities in a multinational or international context, in order to share the costs and the expertise, and to promote quicker and deeper international consensus on safety issues. As dramatically demonstrated by the Chernobyl accident, nuclear safety is typically an international issue. The need for international collaboration will be strengthened in coming years as pressures to reduce budget and manpower resources will grow. The SESAR/FAP group is addressing specific issues in relation to the availability of facilities and capabilities in the nuclear safety area potentially interesting for present or future international co-operation with a view to recommending actions required. A number of criteria are being used to select and prioritise facilities and programmes among those which are at risk of being terminated in the near term, and to establish a short list of facilities for which immediate action should be taken. These criteria are:

- the uniqueness of the facility;
- the willingness of the host country to propose it for international collaboration;
- the usefulness of the results;
- the risk importance of the results;
- how well the facility addresses the issues involved;
- the irreversibility (or not) of closure (mothballing) of the facility;
- whether the issues addressed are primarily a government or industry responsibility;
- the applicability to other issues (potential for broader use);
- cost.

A report on the work of the SESAR/FAP will be submitted to the CSNI in December 1999 and published in 2000 (6). Steps have already been taken to assess further the potential international interest in conducting joint research programmes at the selected facilities through meetings of technical experts and decision-makers. International co-operation agreements are likely to be signed in several areas.

4. Possible OECD/NEA initiatives

There is consensus among nuclear safety research experts that the OECD/NEA has a key role to play in organising reflection and exchange of information on the most efficient use of available technical resources, especially at a time of decreasing research budgets and declining direct government involvement, and in the international management of nuclear safety research facilities and capabilities in a changing nuclear industry. Possible initiatives include:

- pooling/sharing of facilities : setting up joint research projects, centred around a major facility – existing or, if necessary, to be built – which the various countries have agreed forms an international resource which they will jointly support for a reasonable period;
- co-ordinating international research programmes focused on major topics which participating countries utilise to maintain their capabilities;

- centres of excellence: sponsoring the development of selected research facilities into international centres of excellence in areas of work especially important to nuclear safety and the maintenance of competence;
- pooling/sharing of expertise: setting up joint capabilities in areas where national teams would not be able to perform their task effectively, either because of insufficient budgetary resources, or because of insufficient manpower (e.g., as a result of the failure to attract young scientists to replace ageing experts);
- maintaining competence by sponsoring research work in technical areas potentially important from a risk point of view where needs may not appear obvious or immediate but knowledge is highly specialised and adequate experience would be impossible to acquire quickly;
- encouraging training and education in areas where there is insufficient transfer of knowledge from one generation to the next;
- compiling and maintaining relevant data bases on the situation in Member countries;
- encouraging discussions between regulatory authorities, researchers and industry to share views and experiences, and to develop possible solutions.

5. Conclusion

To help maintain an adequate level of capability and competence in nuclear safety is one of the major objectives of the current OECD/NEA Strategic Plan (7). OECD/NEA plays a central role in organising reflection, sharing information, exchanging views and developing proposals regarding the most efficient use of available technical resources, and in the international management of nuclear safety research facilities and capabilities in a changing nuclear industry. A large number of nuclear power plants and associated nuclear fuel cycle facilities will continue to operate in OECD Member countries in the coming decades. Maintaining high standards of nuclear safety and an adequate level of expertise, and enhancing the quality and effectiveness of nuclear regulation are interrelated goals to be pursued as essential requirements for ensuring that nuclear energy can remain a credible option for inclusion in the energy supply mixes of OECD countries.

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INTERNATIONAL ORGANISATIONS ASSURE NUCLEAR SAFETY COMPETENCE

Professor A. Alonso
Counsellor
Spanish Nuclear Safety Council
c/Justo Dorado, 11
28040 Madrid
Spain
aas@csn.es

Abstract

The mandates and statutes of international organisations, such as the International Atomic Energy Agency (IAEA), include articles contemplating the prevention of radiation damage from the peaceful uses of nuclear energy through assuring the safety of nuclear installations and isotope and radiation applications. Such institutions have created Nuclear Safety Departments, as in the case for the IAEA, or specific Committees, as in the NEA, in both cases experts from all nations work in close collaboration with the corresponding staff. Learned institutions, as the International Commission on Radiological Protection (ICRP), and multinational organisations, as the Euratom Treaty, are very active in the development of the scientific background and the setup of standards for radiological protection, while different international associations of regulators develop criteria publish position statements of common interest. The need for nuclear energy and the increasing uses of isotopes and radiation sources assure the continuation of all these institutions and their working methods and so they constitute a safeguard to keep nuclear safety expertise alive and active.

1. Introduction

Nuclear safety competence must be assured as long as the nations of the world remain interested in transforming into useful forms of energy the one liberated in fission or fusion nuclear reactions or linger attached to the beneficial uses of radiation and radionucleides. Nations benefitting from such uses are responsible from keeping such competence alive, not only in the hands of the promoting industry and users but also, and most importantly, within the regulatory organisations.

The increasing globalization of production of goods and services and the new liberalization of trade and commerce, which also include nuclear activities, demands a global response to assure the safety and health of the workers involved and the general public. Even at the earlier time, when such globalization and liberalization was not practiced, the nations of the world did recognize the importance of protecting the health and safety of the individual against the harmful effects of nuclear radiation, which were very well put forward by such old and outstanding organisations as the International Committee on Radiation Protection (ICRP).

The creation of international institutions, such as the International Atomic Energy Agency (IAEA), in 1957 and the Nuclear Energy Agency (NEA) of the OECD, in 1958, mainly contemplated the promotional aspects of the new nuclear discoveries, although putting due emphasis on radiation protection and safety, the importance of which increased with time. Later on, the multinational EURATOM Treaty established in 1957 bounds the nations of the European Union in common regulations regarding radiation protection.

For many years the said international and multinational institutions have been providing satisfactory common understandings on safety matters. The new ideas on globalization and liberalization, mentioned above, are forcing national and international institutions to put forward the harmonization of criteria, methodologies, codes, standards and practices, applicable to old and forecoming technologies, which are also analyzed in common.

This new ideas of globalization, liberalization and harmonization are also to be found in a new set of international organisations which have been created recently by regulatory authorities such as the International Nuclear Regulators Association (INRA), created in 1997, including to the most nuclearized countries of the world; the Western European Nuclear Regulators Association (WENRA), created in 1999 but limited to Member countries to the European Union operating NPPs; the Ibero-American Forum of Nuclear Regulators (FORO), created in 1998 including the Regulatory Organisations of Ibero-American countries with nuclear power plants under construction and in operation.

On the other side, the very same ideas of globalization and liberalization bring to the market competitiveness and deregulation, which may include the temptation to reduce the safety of the installations and the radiation protection practices. This tendency is apparent in many countries and is already affecting the research budgets for further nuclear safety and radiation protection research; plant operating staff is being reduced and operation optimized. Extra care should therefore be applied by regulators to make it sure that nuclear safety and radiation protection are not jeopardized.

The increasing social intervention in the development of nuclear energy programmes and even radiation and isotope uses, both within the national frontiers but also worldwide, is putting a strong pressure against the full deployment of nuclear technology and nuclear applications, demanding also a harmonization of principles on safety and radiation protection practices.

To pay due attention to the statements above, the text will first briefly consider the nuclear safety competence which is needed in industry, users and regulators; to be followed by a description of the major safety activities for which the IAEA and NEA/OECD are responsible; a mention is also expressed regarding the contribution of other international groups, to finish with some conclusions.

2. The competence needed

The cycle of life of a nuclear power plant, and indeed that of a nuclear power programme, includes several stages, as described in fig.1, each one demanding different attention. At present, the activities are mostly concentrated in power plant operation to be followed by plant closure. Within the OECD countries very few new nuclear power plants are foreseen and a few are at the end of construction and commissioning. The OECD itself is considering three major scenarios for the future: (a) phasing out; (b) maintaining the option and (c) reduction followed by renewal. In any case, the immediate future mainly requires competence in operation, the intermediate future will include dismantling and closure and the more distant future may see the starting anew of a new cycle of life and the need for expertise in siting, design, construction and commissioning.

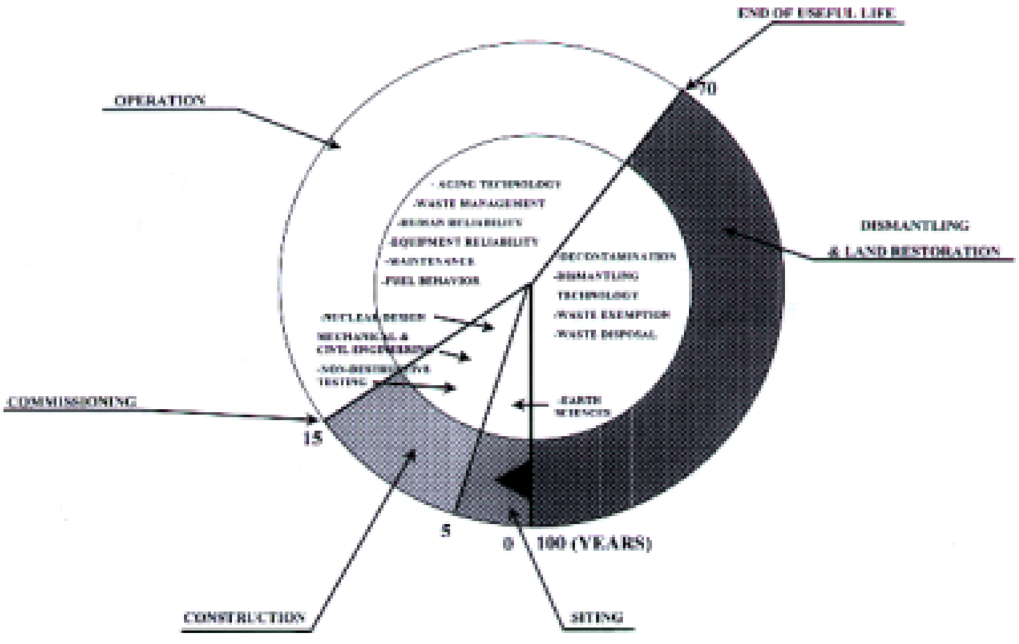


Figure 1. **The Cycle of Life of a Nuclear Power Plant and Representative Technologies**

On plant operation, competence should therefore be maintained in such aspects as: maintenance, management of aging, analysis of operating experience, risk analysis and risk informed regulations, human factors, radiation protection and emergency preparedness. The economic incentives of achieving high burnup and those of using *mixed oxide fuels* (MOX) are bringing new safety issues which have not been yet deeply explored. Likewise, the lack of new projects is producing the need for increasing the life of the existing operating plants, which brings to the forefront the management of aging, and plant life extension.

On plant dismantling and closure the worldwide experience, although considerable, is not yet complete, mainly with regard to the large operating nuclear power plants. The main technologies related are decontamination and radioactive waste management. No specific problems are foreseen regarding low and intermediate activity wastes including short and medium life radionucleides, but the problem becomes acute when considering very low and high activity wastes, mainly those including long life isotopes. The contamination limits of what should be called or not a radioactive waste and the classification of such wastes and their management are pending on an international agreement. The final disposal of high activity long life radioactive wastes has not yet reached a full endorsement and it is not yet based an a completely developed technology, still dependent on needed research.

Non-energy applications are very well developed and used on a worldwide basis. Nevertheless, the recent appearance of illicit trafficking of radioactive sources, the increasing number of reported radiation involved incidents and the presence of orphan sources in metallic recycling mills are facts pointing out towards an increased control on non-energy applications of nuclear technologies within an international context.

2.1 The assurance provided by the International Atomic Energy Agency

The IAEA has recently created a *Department of Nuclear, Radiation, Transport and Waste Safety*, which also includes a *Coordination Office* to increase the effectiveness of the four major fields implemented in the title. The Department includes *five* major activities as follows: preparation of binding and non-binding standards, provision of services, technical assistance to requesting member countries, establishment of coordinated research programmes and the organisation and conduct of large international conferences, specialized workshops and seminars and training courses.

The Nuclear Safety Convention, which entered into force in 1996, and the Convention on Radioactive Waste and Spent Fuel, waiting for signature and ratification of a sufficient number of countries, are recent examples of binding standards produced under the umbrella offered by the Agency. Other useful examples are the conventions on Early Notification of a Nuclear Accident (1986), Assistance in the Case of Nuclear Accident or Radiological Emergency (1987), Physical Protection of Nuclear Material and the Vienna Convention on Civil Liability for Nuclear Damage, among others.

The Agency's programme on non-binding standards is a major international endeavor, which will end in the production of a complete set of safety requirements, safety guides and safety practices in the areas of nuclear safety, radiation safety, waste safety and transport safety. The organisational scheme of such development, including committees and a commission, assure the participation of the best national experts in the drafting and approving such documents, which may be transposed into the national legislation as the need arises.

The technical assistance to Member Countries include a large variety of activities ranging from simple applications of radiation sources in developing countries and isotopes to large scale evaluations of nuclear power plants. In special occasions, extrabudgetary funds are used such as the well known Extrabudgetary Programme on the Safety of WWER's and RBMK's or the Programme on the Improvement of Safety in Eastern Asia. Services provided by the Agency with the participation of international teams include reviews and assessments of issues such as, safety culture (ASCOT), safety significant events in nuclear power plants (ASSET), safety in operation (OSART), probabilistic safety assessments (IPERS) and regulatory organisations (IRRT), among other well known services.

The coordinated research efforts and the multiple conferences, workshops, seminars and training courses organized, conducted and provided by the Agency in collaboration with other international institutions and Member countries are also useful tools to keep the interest and knowledge on safety related matters worldwide and so satisfying the needs for a common response to safety problems.

The work done by the Agency is accomplished by a limited number of staff with the help of national experts, so preserving the national expertise on the most advanced nuclear sciences and technologies. The existence of the IAEA depends upon the will of the countries, but being a member of the family of the United Nations no reasons are foreseen for its disappearance even in the long range, apart from being needed. Therefore, the Agency will remain as a source of high level nuclear safety activities and as a safeguard against the loss of nuclear safety expertise.

2.2 The assurance provided by the Nuclear Energy Agency

The NEA has also recently made a reevaluation of its activities. The Report of the High Level Advisory Group (HLAG) on the Future of NEA (1998), also known as the Birhoffer's report, has concluded that nuclear safety is a top priority for the Agency's efforts. As a consequence of such report, the Agency has drafted a Strategic Plan and has requested from the different Committees a re-evaluation of their activities to increase the efficiency of the work with due consideration to the actual and future needs. The HLAG report also invites the NEA to search for a memorandum of understanding with the IAEA to gain the synergetic effects of collaboration and so avoiding repetitions and gaps in the activities of both organisations.

The NEA has decided to keep alive its traditional five major technical committees: The Committee on the Safety of Nuclear Installations (CSNI), the Committee on Nuclear Regulatory Activities (CNRA), the Committee on Radiation Protection and Public Health (CRPPH), the Radioactive Waste Management Committee (RWMC) and the Nuclear Science Committee (NSC). Nevertheless the number of active Working Groups within each Committee and their terms of reference are being evaluated to adjust their work to the Strategic Plan of NEA and to improve the efficiency of the job while materializing a ten per cent reduction in the budget, which was requested by the Member Countries.

The work performed by the Agency on nuclear safety, radiation protection and waste safety is mainly accomplished by the said Committees assisted by a small but very competent staff. The Committees and the corresponding Working Groups and Task Forces include experts from the Member countries coming from regulatory bodies, national research centres, and in less degree from the industry and the academy.In that way the NEA serves as a forum for discussion of ideas, interchange of knowledge gained and experiences obtained and so helping the harmonization of nuclear safety practices.

But the Committees of the NEA also produce interesting position papers on advanced subjects of common interest, state-of-the-art reports and research reports. One of the major and most profitable activities of the CSNI, and the Nuclear Science Committee, is the organisation of International Standard Problems (ISPs) to validate computer codes against experimental evidence. Up to fifty of this exercises have been performed within the CSNI alone in the areas of thermohydraulics and severe accidents. The Group of Senior Experts on Severe Accident Research (SESAR) has produced most valuable reports on research needs and research facilities.

Most importantly, the NEA keeps the HALDEN reactor, where research is performed within an international context in advanced areas of materials and human factors. The NEA is also the host organisation for international research projects performed in a given country. The OECD-LOFT project represented a large effort on reactor thermohydraulics under design basis conditions, and boosted the knowledge of such discipline in many Member countries. Nowadays, the RASPLAV project, performed at the Kurchatov Institute in Russia, and the Lower Head Failure Project, conducted at the Sandia National Laboratories in the USA, will promote the knowledge of some specific aspects of severe accidents phenomenology. The possible establishment within the Agency of the CABRI Water Loop Project in France will provide needed knowledge on high burnup and MOX fuels.

As in the case of the IAEA, the safety work performed within the NEA is a source of inspiration for the national experts and a provenance for keeping and maintaining the needed expertise on nuclear, radiation and waste safety. Likewise, it is not easy to foresee the disappearance of such Agency. Its recognition of the top priority that nuclear safety should be given would be a needed support to many Member countries. Again, the NEA will stay as a ward to defend and keep nuclear safety expertise in Member countries.

2.3 The assurance provided by other multinational and international associations

It is not necessary to point out the magnitude of the work performed by the International Commission on Radiological Protection (ICRP) on radiation safety. The high scientific level of such long standing Commission will also help to keep expertise in the subjects of its interest.

The Euratom Treaty has bounding power to Member States on radiation protection matters and the Directives emanating from such Treaty has to be transposed to the national legislation. The Treaty does not contemplate nuclear safety aspects as such, but a certain degree of unification of safety practices is coming through the Nuclear Regulators Working Group and other activities. Research is supported through the Euratom Framework Programmes which include a large variety of nuclear safety and radiation protection issues. The European Utilities Requirements for future nuclear power plants are also examples of a common understanding of nuclear safety within the European industry.

The international associations recently created by regulatory organisations also provide added assurance that nuclear safety expertise will be maintained as large as there are applications of nuclear technologies.

3. Conclusions

Nuclear safety has been formally declared as a first priority issue by international organisations such as the IAEA and the OECD/NEA. The globalization of goods and services and the liberalization of trade are creating deregulation and competitiveness with the potentiality for reducing safety levels. The social intervention in the applications of nuclear technology put pressures on regulatory authorities, who must look for a higher efficiency and a harmonization of safety practices.

The competence needed varies with the cycle of life of the given nuclear power plants or the nuclear power programme of a given country. At present, the major emphasis should be put on operation and later on decommissioning. New projects will require additional expertise regarding siting, design and commissioning.

International organisations are safeguards against the loss of nuclear safety expertise in Member countries by providing fora for sharing knowledge and experience and by organizing international research projects, conferences, seminars and training courses. The binding Conventions deposited in the IAEA provide additional assurance on the need to keep the necessary nuclear safety competence.

HIGHLIGHTS OF THE INTRODUCTORY SESSION: INVITED PAPERS

L. Vöröss
Deputy Director General
Hungarian Atomic Energy Authority
Margit krt 85
114.Pf.676
H-1539 Budapest, Hungary
voross@haea.gov.hu

Competence is not only a matter of knowledge but also of behaviour at the level of individual and organisation. The trends towards deregulation and privatisation of the energy markets raise special constraints for the nuclear industry and regulators which complicate previous relationships between the parties. Due to the lack of construction of new plants and the ageing of those which exist, the numbers of staff having an understanding of safety cases and the processes used to license nuclear plants are declining.

The comprehensive survey carried out among EU countries and its analysis of education has revealed a general trend of ageing facilities and reduction in number of research reactors, education facilities and research laboratories as well as academic staff for future training. Changes in the skills needed for nuclear jobs can be observed: there is increasing demand for jobs like waste management and disposal, dismantling of nuclear facilities, decontamination, ageing processes. However, recruitment of talented students even to these fields is difficult.

A similar survey carried out in the USA led to the same conclusion.

Nuclear engineering education has shown a marked decline in the past decade in spite of the fact that the job market has been strong. Some innovative actions from the educational organisations have been introduced ranging from advertising, the provision of research funding and summer schools to improve recruitment. In Finland stronger governmental support provided to the Nuclear Energy Research Initiative programme has been reported.

The British industry has recognised the importance of the issue of maintaining competence and has become more proactive in its recruiting processes: visitor centres and coach trips around its sites as well as sponsoring both students and nuclear research at universities, and collaboration with other institutions in the international research areas can be mentioned as examples. An urgent investment in nuclear education, training and research is needed.

A promising initiative of the European Nuclear Society (ENS) is the establishment of the Young Generation Network aiming at involvement of young scientists and engineers into advertising the nuclear technology among the young. Improved public relations, education programmes and support for know-how transfer between generations seem to be the most effective tools to improve the image of nuclear power among the young.

The international organisations like IAEA and OECD/NEA play significant roles in the exchange of information which is an essential part of maintaining competencies amongst those involved in the nuclear industry. The harmonisation of criteria, methodologies, codes, standards and practices for the whole life cycle of the nuclear facilities helps solve problems in ensuring a consistent response to the challenges of the privatised and deregulated environment. Because the funding levels of national governments safety research programmes have been reduced over recent years, international efforts are necessary to keep alive those research facilities which are available for co-ordinated research programmes in safety significant areas like severe accidents, human behaviour and ageing.

SESSION A

How To Incorporate New Safety Capabilities Through Education and Training

Chairman: Professor Z. Szatmáry

TRAINING AT THE MASTERS DEGREE LEVEL IN PHYSICS AND TECHNOLOGY OF NUCLEAR REACTORS IN THE UK

D. R. Weaver
School of Physics and Astronomy
The University of Birmingham
Edgbaston, Birmingham, B15 2TT, UK
d.r.weaver@bham.ac.uk

Abstract

This paper discusses the current situation of university-based training for the nuclear power industry in the UK, drawing on information gathered as part of the survey for a review currently being undertaken by the Committee for Technical and Economic Studies on Nuclear Energy Development and Fuel Cycle (NDC) of the Nuclear Energy Agency (NEA) of the OECD.

A particular focus will be the Physics and Technology of Nuclear Reactors MSc course at the University of Birmingham. In the past there were other similar MSc courses in the UK, but through the evolution of time the Birmingham course is now unique in its role of providing masters level training so specifically aimed at the commercial nuclear programme.

Mention will, however, be made of other training at the postgraduate level elsewhere in the UK.

A description is given of the need to consider a new form of relationship between industry and university in order to provide optimise the provision of masters level training.

1. Introduction

With the early entry of the UK into the commercial application of nuclear energy the need for training in nuclear technology was obvious from the 1950s. The university sector was encouraged to play its part and a number of courses were set up at both undergraduate and postgraduate level.

The University of Birmingham started teaching reactor physics at the Masters degree (MSc) level in 1956. Other universities also started courses, principally in Engineering Departments. Thus, for example there was a Nuclear Engineering undergraduate course at Manchester and a Masters level course at Queen Mary College (QMC) in London. Research reactors were established at Imperial College, QMC, Risley (to serve Manchester and Liverpool) and in East Kilbride for a consortium of Scottish universities.

Over time the number of courses has reduced considerably; there are no longer any nuclear specific undergraduate courses in the UK, nuclear engineering being represented by option courses within more general engineering degrees such as at Manchester and Cambridge. Of the reactors, only the one at Imperial College survives – indeed it is now the only research reactor in the UK (outside the specialist needs of the military).

At the Masters level the Birmingham Physics and Technology of Nuclear Reactors (PTNR) MSc is now the only course in the UK specifically oriented at training people for the nuclear industry. There are a number of more broadly based radiation related courses, for example at Surrey and our sister course at Birmingham in Applied Radiation Physics. There has even been the recent development of a Radiometrics course at Liverpool with the strong encouragement of BNFL. However, none of these courses is so specifically directed at the nuclear industry as is the PTNR course.

Close liaison with the nuclear industry is important for any university involved with nuclear power matters. In the UK we are fortunate to have the "Nuclear Academics Industry Liaison Seminar" (NAILS) where representatives of the universities involved in teaching and research meet on a regular basis with representatives of the industry under the sponsorship of the British Nuclear Industry Forum (BNIF). Combined with an annual meeting where PhD students and staff describe current developments usually in the company of representatives from industry, there are reasonable arrangements for national interaction involving the nuclear power related university departments.

Interaction does not guarantee existence, however. Critical situations can occur. Recognising such a situation in relation to nuclear chemistry in the UK, BNFL has recently established a "Centre of Excellence" at Manchester in order to preserve its core competence in this area.

In the case of Birmingham we are very grateful for a wide range of support from the industry: finance, specialist lectures, visits and even a reactor safety exercise. In the last 15 years, particularly, companies have provided sponsorships of students and have become more involved in provision of specialist lectures – from short courses such as Non Destructive Testing, to single talks illustrating particular aspects of a company's work. The reactor safety exercise is, perhaps, of special interest to this conference; a problem is set to the MSc students towards the end of their training which is based on a realistic situation at a power station. They are given a day to respond to detailed questions and their presentation at the end is commented upon by a member of staff from the industry with particular knowledge of safety cases.

International links are also important and I would cite particularly the Frédéric Joliot/Otto Hahn Summer Schools in Reactor Physics held alternately at Cadarache and Karlsruhe. These have been extremely useful in providing opportunities for new recruits to the nuclear industry from Europe and the rest of the world to learn of the current developments in our technology and to share experiences amongst themselves. The benefits also extend to those of us involved in the planning of these summer schools and the opportunities to meet with colleagues at the Executive Board Meetings for the Summer School are most valuable. CEA are to be congratulated on initiating and sponsoring this activity.

We also need to consider the training provided by the companies. To quote from the UK section of the draft of the OECD/NEA report "The Survey and Analysis of Education in the Nuclear Field"

"Once employed, companies offer training schemes to support both broad based knowledge and specific skills development. Training is designed for both new graduates and experienced staff with the aim of increasing the competence of the trainees in their specific function within the organisation. Although a wide range of courses is being operated with a strong focus on individual company needs, much training is in response to regulatory requirements. Companies fund their own in-house training."

I believe the comments about focus and response to regulatory need are well made. Clearly industry is making good use of newer training aids such as computer based learning; however, with smaller staffs I have had it reported to me that it is increasingly difficult to provide the background mentoring support that these less personal systems require.

2. The changing scene

Life does not stay still. In order to understand the situation in which the nuclear industry and higher education finds itself in 1999, it is useful to review the changes that have occurred in the structures of both the industry and the education system. It is appreciated that this is a rather UK specific viewpoint, but I believe there may well be parallels in other countries. By sharing experiences, I hope we can learn from each other how to optimise the sometimes delicate interfaces between industry and academia.

2.1 The changing face of the UK nuclear industry

At the point where the first truly commercial nuclear power stations came on stream in 1960 the research and development of nuclear power was in the hands of a single government organisation, the UK Atomic Energy Authority (UKAEA). Equally, the responsibility for the generation of electricity in England and Wales was in the hands of another nationalised body, the Central Electricity Generating Board (CEGB).

Since about 1970, this situation has changed dramatically. The UKAEA was broken up; the specifically military related role passed to the Ministry of Defence and the fuel fabrication and reprocessing activities were passed to a new, but still government owned company, British Nuclear Fuels (BNFL).

Then, in the 1980s, the UK privatised the electricity supply industry and this has led to the current situation where a company quoted on the London Stock Exchange, British Energy, is responsible for the newer Advanced Gas Cooled Reactor stations and the Sizewell B PWR station. The older Magnox power stations stayed in government hands and have been merged into the BNFL business within the last couple of years.

Added to this, the privatisation policy which had affected the CEGB led also to the selling off of a considerable portion of UKAEA to form AEA Technology, while the government retained (under the UKAEA name) the decommissioning and waste management responsibilities and, at Culham, the fusion activity.

The last year has seen further change. BNFL and Morrison Knudsen have acquired the bulk of the Westinghouse nuclear business. Meanwhile, the management of the Magnox Generation business within BNFL is in the process of being reorganised involving a joint venture with AEA Technology. Added to this, the Government has announced its intention to privatise a proportion of BNFL in the near future.

So why does this evolution of company management structures matter? The point is that the changes in the university sector, which will be outlined in the next sections, mean that the universities are less likely to find governmental sources of funding for their activities. With a more fragmented industry, it is less straightforward for the universities to establish and maintain funding routes and that impacts on their ability to assure provision of nuclear technology training into the 21st Century. By implication this situation must have an impact on the Assurance of Nuclear Safety Competence.

2.2 Changes within the UK University System

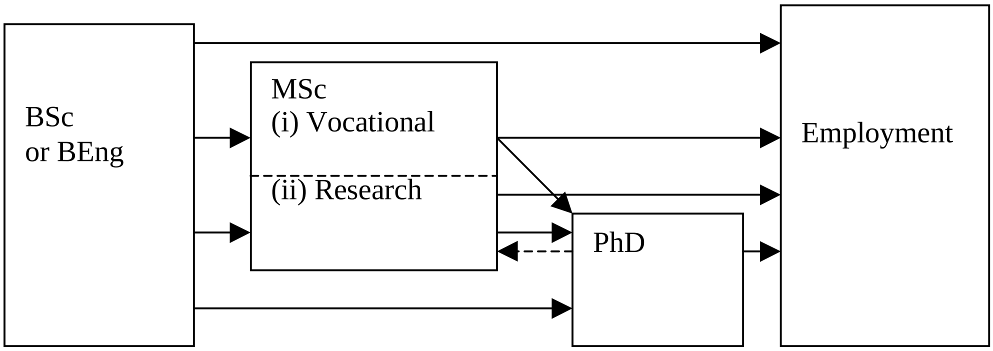
There are two aspects to this part of the discussion:

(A) changes in structure; and
(B) changes in funding of students,

both of which impact on the way students come forward to study of nuclear technology. For obvious reasons I will concentrate on science and engineering disciplines.

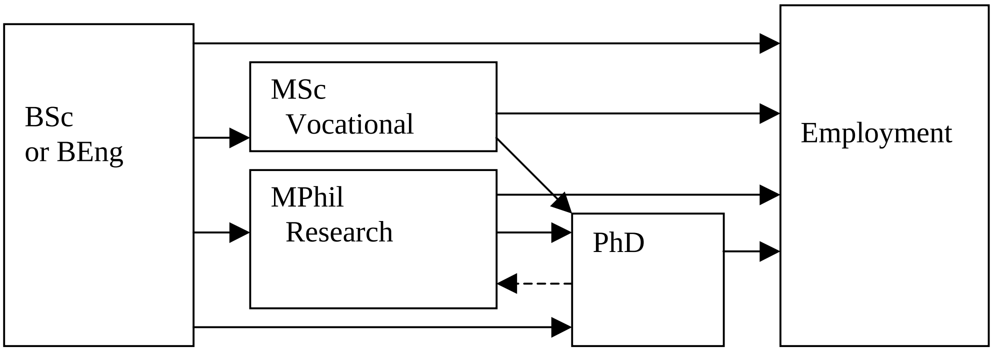
In the UK the progression from a first degree (BSc or BEng) to the PhD research degree has never (yet) required an intermediate MSc stage. Rather, the MSc traditionally had two very different roles: (i) as a *vocational* taught course, normally lasting one year, with the emphasis on coursework but with a project element typically taking up the last third of the course; (ii) as a research degree, shorter than a PhD, for those either unable to contemplate spending the time to gain a PhD or as a preliminary research training for those with a first degree background unsuitable for direct entry to a PhD. Sadly for the perception of the value of an MSc, this second type has also been used as an "escape route" for those adjudged to be unsuitable for completing a PhD.

Figure 1. **Old Style (the dotted line indicates the “escape route”)**



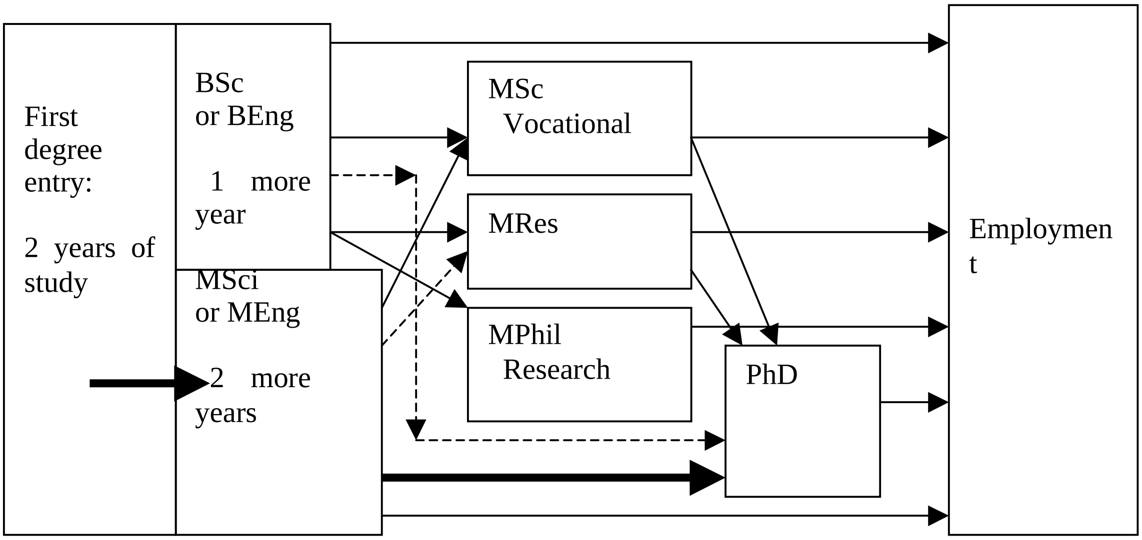
One positive change that is happening is that the confusion over the types of MSc is being removed by renaming the research Masters under some title such as MPhil, see Figure 2.

Figure 2. **Newer Style**



However other changes are making the situation more complex. Starting with the engineering degrees and moving to disciplines such as chemistry and physics, there has been a perception that the traditional three year first degree was too short to prepare graduates for the full range of potential postgraduate activities. Thus the 4 year undergraduate MEng, or MSci has been introduced. Within physics this has been sufficiently recent that it is not yet a requirement that a student has to take an MSci before proceeding to a PhD, but it is likely to progress that way. Added to this, a new MRes degree has been created to provide a conversion route for students to move towards a PhD in an allied discipline.

Figure 3. **Current Style (dotted lines indicate less common routes, see text for meaning of bold arrows)**



It is patently obvious that the possible routes for the science and engineering graduates are becoming more complex.

If we now consider the funding of students, the meaning of the bold arrows becomes clear. At first degree level students are funded by a combination of loans and support from their parents, the latter having a safety net of some local government funding if parents are unable to afford to contribute. The tuition fees are provided directly to the university from the local government authorities.

Thus it is to the advantage of university departments to encourage as many students as possible to take the 4 year MSci and MEng routes as possible as this maximises their guaranteed tuition fee income. However, this means that students leaving those 4 year degrees have greater debt burdens than those leaving three year degrees.

Equally, university staff have a research role of their own and it is also to their advantage to see as many good candidates coming forward as potential PhD students as possible, it is clear that the route indicated by the bold arrows in Figure 3 indicate the preferred route recommended by many academics to students unsure of their direction of development.

Funding of postgraduate training (MSc, MRes, MPhil and PhD) has been through a combination of central government funding and individual company sponsorships. However, the government organisation that has had the role of managing the support to the MSc and the research degrees (EPSRC) has recently embarked on a process whereby support for vocational MScs is (a) focused on its research priority areas and (b) is to be time limited to a maximum of five years with the expectation that industry will increasingly pick up the costs until, at the end of the five years, EPSRC support is withdrawn.

We are therefore in a situation where funding for MSc programmes is increasingly difficult from government funds (nuclear power does not seem to fit the current EPSRC priority areas well), and students are both in greater debt on graduating from their first degrees and being encouraged into a research oriented route. It is therefore not surprising that we are in a situation where the viability of vocational, Masters-level courses is under threat.

3. Managing change

In the same way that any industry has to consider its business priorities, the universities have to look at the viability of particular facets of their research and teaching. As part of this process the University of Birmingham has recently sought views from advisors within the nuclear industry as to the desirability of continuing the Masters level teaching.

It was clear from these discussions that the advisors felt that this form of provision should be retained. They felt that the benefits to the industry focus in three directions.

- the maintenance of a skills source independent of particular nuclear companies;
- a route to recruitment of new graduates who have demonstrated an interest in the technology;
- provision of In-Service or Continuous Professional Development courses for staff already in post.

Indeed, despite the somewhat negative aspects of the current scene, as outlined in the previous section, they felt that there are current developments that make it an opportune moment for the industry through partnership with the university to participate in the evolution of teaching material to optimise the provision of training for their needs. These points will be amplified below.

3.1 The Maintenance of a skills source

We have seen how the UK nuclear industry has been evolving. With a significant proportion now privatised it is natural that all technological infrastructure resources within companies are being reduced. The effect on training provision is just part of that overall picture.

The need to reduce overall staff numbers as part of the process of guaranteeing a company's financial well being, also has its effect on the availability of staff time for both on the job training of new entrants and also the provision of specialised courses. In its recent discussion with the advisors it was clear that, even for one of the major players, the provision of appropriate level reactor physics training for relatively new entrants was no longer easy to organise because of the need to release staff from their normal activities in order to undertake the teaching.

Another trend is for companies to operate separate business units, which are required independently to demonstrate their business viability; but this means that the benefits of sharing of resources across a larger organisation can be lost.

Similarly, the Oldbury Training School used to serve all of the CEGB's nuclear stations. Now, training is separated between British Energy and BNFL Magnox and the simulators have been relocated to the relevant power station.

This raises the question of how much the need to focus on core objectives a particular company in a market led environment also tends to focus the training of staff. How desirable is it to have training totally driven by market forces and at what point do we reach the stage where training becomes so job-specific that the ability to appreciate a wider picture becomes lost?

The universities, in contrast, provide an independent resource which can be accessed from across the industry and provides the breadth of knowledge that enables participants in the university courses to see that there are issues wider than the single company view. In addition, the use of university courses, so long as they are appropriately tailored to industry's needs, can save the time of company staff in providing on the job training.

3.2 Provision of motivated graduates for recruitment by the industry.

Despite the negative aspects of the evolution of the UK nuclear industry leading to some of the lowest recruitment levels seen in recent years, the Birmingham Physics and Technology of Nuclear Reactors MSc has enjoyed particular success in placing its graduates into employment in the nuclear industry. In a survey of students graduating since 1990, 84% went on to use their MSc in their first employment. This percentage is believed to be unusually high for MSc courses and represents both the abilities of the individual students but also the linkage between the industry and the MSc course staff so that students can be advised of future employment opportunities at an early stage. A further important use of graduate from the MSc is through the fast-track, 2-year PhD programmes that are available for MSc graduates at Birmingham. The industry has used this frequently in recent years.

3.3 Lifelong learning and continuous professional development

Within the UK it is clear that the old, sequential concept of progression from school to higher education to employment is being replaced by a concept of "Lifelong Learning" where periods of study are undertaken both, during and between employments.

Some parts of the nuclear industry (obviously biased towards those companies geographically close to Birmingham) have over many years used parts of the Physics and Technology of Nuclear Reactors MSc as an "In-Service" training course for employees already in post.

However, there is a growing interest in the UK in "Continuous Professional Development" (CPD), a somewhat more formalised arrangement of training within employment whereby academically accredited courses are taken by employees and these are used in the process of reaching qualifications such as CEng (Chartered Engineer) status from one of the awarding bodies.

As a result, at Birmingham we have embarked on a process of making more of the MSc courses available for part time study so that employees within industry can register to take part or all of an MSc. Because of the spread in location across the UK of potential participants, we are building in so-called "Distance Learning" facilities so that it is not necessary for staff to attend the university for all of the taught material. During 1999/2000 I am using a Study Leave opportunity to develop this part time, Distance Learning MSc concept. It is an indication of the support from BNFL of this development that they have provided the resource to allow me time away from my normal teaching to work on this project. Clearly they are tangibly supportive of the development, but the discussions with our advisors indicate that the breadth of support exists beyond that one company.

3.4 Partnership

I have discussed how there is a need for companies to optimise their training effort. We have also seen that governmental sources of support are now disappearing quickly. As a result the British Nuclear Industry Forum – the trade association of the UK commercial nuclear industry – is working with the University towards the formation of a Partnership between the nuclear industry and the university. The aim is the provision of a training resource which suits both the recruitment and CPD needs of the industry.

It is right that in a partnership both sides have an involvement in the management of the activity. Thus the industry will be involved in the continuing evolution of the course material so that they can (jointly) optimise it for their needs. The university, on the other hand, will provide the independence and academic standing that is required for the course and its constituent modules in order for them to have the appropriate recognition that qualifications awarded will be suitable for the CPD purposes.

The nuclear industry has always had a strong involvement with the Birmingham MSc course; however, the process will be more direct under a partnership.

4. Conclusions

I have discussed how the present time provides an opportunity for a new Partnership between the nuclear industry in the UK and the provision of master level training to suit the needs to the industry as we embark on the 21st century. We are at an exciting stage. However, it needs to be clearly understood that should the industry not grasp the opportunity, there is a very real chance that the resource at Birmingham could disappear very rapidly.

Acknowledgements

I am grateful to: BNFL for support towards the development of the new part-time and Distance Learning facilities; to British Nuclear industry Forum for supporting the Partnership concept; and to the IMC for assistance in attending this meeting.

POSTGRADUATE EDUCATION IN NUCLEAR ENGINEERING: TOWARDS AN EUROPEAN DEGREE

Michel Giot
Université Catholique de Louvain
Comité Directeur du DES en Génie Nucléaire
Unité TERM, 2 place du Levant,
B-1348 Louvain-la-Neuve, Belgium
giot@term.ucl.ac.be

Abstract

This paper presents the postgraduate degree in nuclear engineering jointly organised by four universities of the French Community of Belgium, and its possible evolution towards an European degree. The project includes the location of the programme outside the partner universities at the premises of the SCK•CEN, a modular structure of the curriculum, and an increased co-operation of the teaching staff within small groups of experts including academics, researchers and practitioners from the nuclear industry. This programme would favour the exchange of students and professors through a network of top quality European institutions pursuing the same teaching objectives.

1. Introduction

Higher education in nuclear sciences, in nuclear medicine and in nuclear engineering is well established in the Belgian universities. Since the end of the fifties, each major institution offers some specialised programmes in these fields. This corresponds to the large expansion of the nuclear technologies in our country which has developed almost all types of medical, industrial and research activities.

Education in Belgium is presently organised at the communities level. In 1996, the four schools of engineering of the French Community of Belgium* joined their efforts to propose a common postgraduate university degree in nuclear engineering instead of the four pre-existing curricula running in parallel. A similar organisation had been set up a few years before in the Flemish Community. Both remaining curricula consist in one year programmes. The number of students in each of them is rather modest, but seems to correspond to the local industrial needs. Besides these postgraduate diplomas, some engineering degrees at undergraduate level – like the programme of ingénieur civil physicien organised by the Free University of Brussels – incorporate a sound basis in nuclear engineering. Such curricula are not considered here. This paper is focused on the one year postgraduate programmes.

The question discussed below is how to pursue and optimise this educational effort, knowing that the university investment in this sector in not guaranteed for the future. Furthermore, in Europe, it is mandatory that new concepts of nuclear engineering education at University level take account of three major and relatively new changes in the whole engineering education system: the introduction of an European dimension, the development of quality assurance, and the political decision to move towards a common European structure of the curricula. These three aspects complement the “vision” for the 21st century presented in the summary published by Freidberg (1999) after the report prepared by the Nuclear Engineering Department Heads Organisation of the United States. Some other differences are linked to the postgraduate character of the Belgian programmes.

2. Present situation and needs for change

In the French Community of Belgium, the one-year programme, called “DES, (Diplôme d’Études Spécialisées)” is designed for young engineers and scientists with conventional engineering skills, such as thermodynamics, fluid mechanics, heat transfer, materials, chemistry, control systems, informatics, who wish to specialise in the field of nuclear power plants and related applications. Merging the programmes created an opportunity for upgrading them: the new curriculum is considered as pertaining to the “third cycle” (post-master education). A Steering Committee composed of eight academics is the co-ordinating body.

For each of the basic disciplines, the students can choose between several courses taught at different locations. Belgium being a small country, shuttle from one town to another is no major difficulty. In addition, the advanced courses are jointly organised and are also offered in the framework of continuing education for practitioners. These courses as well as the theses and the internships are presently organised in co-operation with the nuclear energy research centre of Mol (SCK•CEN) and the industry.

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* These schools belong to the following Universities : Université libre de Bruxelles, Université de Liege, and Université catholique de Louvain, and include the Faculté polytechnique de Mons.

The DES started in 1996-97. After three years of operation, we can say that the recruitment of students is stabilised around five students per year. Teaching has created new opportunities of inter-university co-operation between the involved academics. Contacts have been taken through BNS (Belgian Nuclear Society) with the Belgian Nuclear Managers – an informal meeting point of the industry managers – to suggest them to better advertise the industry recruitment needs of specialised engineers. As a result of this action, a yearly grant has been established to support the best students who undertake the studies.

Narrow contacts between academics, students and the industry is one of the necessary conditions for high quality teaching in engineering. There is no problem to ensure these contacts in Belgium, and we do not foresee any problem for the mid-term future. The main issue for the future is the availability of a top level academic staff. Indeed, there is a risk of decline of university research activities in several key areas like reactor physics, thermal-hydraulics and chemical engineering applications. This would affect the quality of teaching because direct reference to research is another necessary condition for high quality teaching.

Therefore, it is believed that the different partner universities in the DES should concentrate their efforts, each partner accepting to support research and teaching in the long term in a limited number of areas. Further, it is felt that such an effort could attract more graduate students from Belgium and abroad, justify more funding, and stop the deflation spiral.

3. Objectives for a new organisation

For the reasons presented above, the Steering Committee of the DES is willing to make further steps towards a more complete integration. New plans include the regrouping of the teaching activities at SCK•CEN and merging with the more or less similar curriculum existing in the Flemish Community. The teaching language could be English. By another way, contacts have already been taken with the French INSTN (Institut National des Sciences et Techniques Nucléaires) to increase the present co-operation between the DES and the “programme de génie atomique”. This clustering effort could be the first step towards the creation of an European network.

Before going into more details, let us list the objectives of a more complete integration at the Belgian level.

a) In the search of excellence of any field of engineering education, a **critical mass** appears to be an important factor. In the present case, thanks to the number of presently available teachers in the various fields of nuclear physics, chemistry and engineering, the critical mass of faculty staff can be obtained by concentrating the courses at the location where the most important research activity is located, the SCK•CEN. This type of organisation would enhance the co-operation between the partner universities and the nuclear research centre for the benefit of the students, of the researchers and of the teachers themselves.

b) Quality could be improved by forming for each discipline or course a **small team of professors, researchers and industrialists** working together. It must be recognised however that such an organisation requires a much stronger co-ordination than the present DES and a more important involvement of the nuclear industry.

c) The regrouping should enable new possibilities of co-operation at the European level, in order to enhance the **European dimension** of the curriculum.

d) The **postgraduate** character of the programme needs should be reinforced in view of its specific objective of high level specialisation. The second cycle (undergraduate) objective is “to learn how to learn”. Here we deal with students who have already acquired this skill, and want to go a step forward in a well-defined discipline. However, in the line of the declarations of the ministers of education in Sorbonne (1998) and in Bologna (1999) the appropriate denomination for the degree would be a “master degree”.

e) A long term contract between the universities should guarantee the **continuity in the effort**. In this respect, the quality of the inter-disciplinary teaching environment, the presence of a sufficient number of students, the reference to research, the contacts with industry and the international character of the programme appear to be the most relevant factors for attracting the interest of the universities.

f) The schedule of the courses must be **compatible with part-time employment** of the students in the industry. According to a long tradition part of the students consist in young engineers working in the nuclear power plants.

g) Part of the courses should be designed for the purpose of **continuing education** or training of scientists and professional engineers. Flexibility is required to continuously adapt the programme to the needs, and maintain an equilibrium between theoretical background and applications.

h) A clear and **active support from the industry** is an important credibility and quality factor for such a programme.

i) An **European recognition** of the curriculum, as one of the best, appears as a condition for getting adequate support in the long term.

To summarise, quality, flexibility and European dimension are the key-words of the proposed clustering.

4. The role of the nuclear research centre

According to its official missions as an institution of public utility, SCK•CEN is a “centre of knowledge in nuclear science and technology, and related safety aspects”. Its mission statement reads: “Through research and development, education, communication and services, SCK•CEN shall innovate with a perspective of sustainable development in nuclear safety and radiological protection, industrial and medical applications of radiations, and back-end of the nuclear fuel cycle”.

With a staff of 600, the Centre has a lot of R&D activities of high relevance for nuclear engineering education. Let us name a few:

- the VENUS facility for experiments of reactor physics with new types of fuels;
- the operation of the BR2 reactor for testing materials, producing radioisotopes, etc.;
- the MYRRHA project of a small scale ADS (accelerator driven system) for the study of transmutation;
- HADES-PRACLAY, the first European underground laboratory to study the long term storage of high activity level waste in clay;
- the dismantling of the BR3 reactor – the first PWR built in Europe, and also the first PWR reactor to be dismantled in Europe;
- the radiation protection and safeguards division covering radiobiology, radioecology, nuclear measurements and assessments and decision methodologies.

Recently the decision has been made to extend the field of research to the problems related to the interactions between Science-Technology and Society.

The Centre participates in many international and European research programmes. It has a special programme for PhD students in co-operation with the Belgian universities, and offers grants on an international basis to post-docs who want to come and work during two years in one of its labs. The Centre has an extensive specialised library, and organises a lot of advanced courses and seminars, as well as practical training. From a practical point of view, food and lodging are available in the close vicinity of the premises.

SCK•CEN would like to contribute to the creation of an European network in nuclear engineering education in co-operation with the Belgian universities. The location of SCK•CEN and of the European Joint Research Centre IRMM at Geel, in an area where not only R&D, but also industrial activities (Belgonucléaire, Belgoprocess, FBFC) take place, make it a suitable candidate for developing a high level engineering education project in an international context.

5. Characteristics of a possible new organisation

The programme would involve a fixed set of basic courses organised in a modular way during 20 weeks, and the subsequent preparation of a final thesis during 14 weeks in industry or in a nuclear research centre.

5.1 Modularization of the programme and teaching teams

The presently discussed structure of the programme is modular. Each course would be concentrated over a short time span, e.g. two or three weeks, in order to make easy the invitation of specialists, including foreign experts, and the use of the courses for continuing education purposes. Practical exercises including the use of software's such as nuclear safety codes, laboratory demonstrations and visits of nuclear installations would run in parallel with the theoretical parts of the courses. A system of continuous assessment of the students would be developed.

The basic courses would be more or less identical to the present one. They are listed below with their corresponding numbers of modules. These numbers are not yet fixed; they have just been introduced here to check the feasibility of such modular structure.

	Modules
Introduction	1
Nuclear physics and radiation detection	2
Nuclear reactor theory and codes	3
Nuclear thermal-hydraulics	2
Operation and control	2
Reliability and safety	2
Fuels, fuel cycle, wastes	2
Structural materials	2
Radiological protection	3
Regulation, Communication	1
Total	**20**

Each module corresponds to 15 hours of lectures and 15 hours of tutorials, demonstrations, visits, etc., i.e. the schedule for one week. It seems advisable that no more than two courses would alternate during the same week.

Each course would be taught by a team involving academics, researchers and practitioners. The accent would be put on the personal work and the work in team of the students. This requires an efficient programme management, and a continuous evaluation of the skills and knowledge acquired by the students.

5.2 Final thesis

The objectives of the final thesis would remain unchanged with respect to the present situation : in his (or her) final thesis, the student analyses a topic or develops a project of nuclear engineering where he (or she) applies the concepts and methods learned during the first degree courses as well as in the modules of the DES. The only difference is that in the proposed organisation scheme, the final thesis would be prepared during a period of time where no courses take place. This way to proceed increases the possibilities for achieving the thesis in an industrial or research environment in Belgium or abroad.

As it is today, the final thesis is placed under the responsibility of an academic of one of the partner universities, with the assistance of a mentor. The thesis is presented at the end of the academic year in front of an inter-university jury with participation of some external practitioners.

5.3 Examinations

Besides the continuous evaluation, and the credits obtained by a successful participation to the individual courses, the students would have to pass a final examination in front of the same jury as for the thesis. The final examination would enable to assess the global level of competence acquired. Not much extra time would be foreseen for the preparation of the final examination. The relative importance of the final thesis in the total amount of credits would be 25%.

5.4. Contractual agreements

According to the currently applicable rules, the partner universities of the French Community of Belgium sign a common agreement, where the part of the programme supported by each partner is indicated. The contract is valid for a limited period (3 or 5 years) with renewal by tacit agreement, and periodic quality assessment. In this particular case, the non university partners, namely the SCK•CEN and the industrial partners should sign an agreement with the partner universities. The management of the programme would be the responsibility of a management committee composed and operating under agreed rules. Among the other points to be agreed upon, let us mention the admission conditions for the students, the administrative and academic calendars, the location, the specific rules for the operation of the examination jury, etc.

According to the decree presently in force, the students can take full benefit of national or international exchange programmes (e.g. SOCRATES-ERASMUS) : the ECTS (European Credit Transfer System) is normally applied. There would be no administrative difficulty for our students to follow some courses taught by a Flemish university, or in Saclay, München or Pisa, or any other top level institution. The final thesis can also be prepared in the framework of an agreement with a foreign institution.

Merging the total programme with the programme of the Flemish Community of Belgium is not a standard administrative case. However, there exist some examples of such co-operations with several European partners for European degrees. In such cases, the teaching language is usually English. On a case to case basis, the European degrees include students' and/or teachers' mobility. It must be recognised that their management and practical organisation require a very significant effort.

5.5 Financial matters

A joint programme of the French Community of Belgium is financially supported in a way similar to the other university programmes, except that the partners share the expenditures and the incomes. The proposed organisation of the nuclear engineering programme at a location outside the universities implies some additional costs which should be covered by extra revenues. In particular, the logistic and scientific costs supported by SCK•CEN should find some counterpart. It is hoped that the creation of an European degree in nuclear engineering delivered by a network of universities would find an appropriate support from the national and European Authorities.

6. Conclusions

The project takes into account the experience gained during three years of successful operation of a combined postgraduate degree in nuclear engineering, with four partner universities. It aims at further developing this co-operation by concentrating the programme at a single location. The advantages offered by the selected location, the SCK•CEN premises at Mol, have been briefly described.

The proposed programme could be built in the framework of a new European degree. Its objectives and its main operational characteristics have been defined. The practical details reported in the paper are, of course, subject to further discussions. They have been given in order to enable the reader to better understand how the programme would work, and how the objectives could be achieved.

It is hoped that this paper will further stimulate the discussions in Belgium and in the OECD countries around the important topic of the education of the next generation of scientists and engineers in nuclear engineering.

Acknowledgements

The author gratefully acknowledge the contributions of his Colleagues of the Steering Committee and of the SCK•CEN to this paper, and the fruitful discussions in a friendly atmosphere.

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GRADUATE NUCLEAR ENGINEERING PROGRAMMES MOTIVATE EDUCATIONAL AND RESEARCH ACTIVITIES

Borut Mavko
"J. Stefan" Institute
and
Faculty for Mathematics and Physics, University of Ljubljana
Ljubljana, Slovenia
borut.mavko@ijs.si

Abstract

Some fifteen years ago the University of Ljubljana, Faculty for Mathematics and Physics together with the national research organisation the J. Stefan jointly established a Graduate programme of Nuclear Engineering. From the onset, the programme focused on nuclear technology, nuclear safety, and reactor physics and environment protection.

Over the years this graduate programme has became the focal point of nuclear related, research and educational activities in Slovenia. It has grown into a meeting ground for recognised national and distinguished foreign educators and experienced professionals from the industry. In conjunction with an important national project, supported by the Slovenian government, entitled "Jung Researcher" it also enhances the knowledge transfer to the next generation.

Since the programme was introduced, the interest for this programme has been steadily growing. Accordingly, a number of PhD and MS degrees in NE have been awarded. The graduates of this programme have encountered very good job opportunities in nuclear as well as in non-nuclear sector.

1. Introduction

In 1998, Slovenia produced 12 895 TWh net electric energy, which is approximately 4.3% more than a year ago. The Krško NPP produced 4.8 TWh electric energy and the production of net electric energy from the NPP decreased by approximately 0.5%, but it represents approximately 36.7% of all electric energy produced in Slovenia. Of the 10.97 TWh electricity consumed in Slovenia the NPP Krško covers about 22% of needs.

Construction of the Krško Nuclear Power Plant, 634 MWth PWR designed and built by the Westinghouse Corporation, began on February 1, 1975. The plant became a nuclear facility in May 1981 when the initial core was loaded. The first criticality was achieved on September 11, 1981. On October 2, 1981, the generator was synchronised to the grid for the first time. In August 1982, the plant reached the 100% power level. On January 1, 1983, the plant started its commercial operation.

The year 1998 was in all aspects the best calendar year in history of commercial operation of the Krško NPP. Energy production was about the same as in 1997, which has been the record year until now. In 1998, NEK exceeded the Institute of Nuclear Power Operation (INPO) year 2000 goal for seven Performance Indicators: Unit Capability Factor, Unplanned Capability Loss Factor, Unplanned Automatic Scrams per 7 000 Hours Critical, Volume of Low Level Solid Radioactive Waste and all three Safety Systems Performances. The rest of the Performance Indicators were very close to the goals set by the Institute of Nuclear Power Operation.

The year 1998 was also the first calendar year without reactor trip. There were no unplanned shutdowns, as well as no significant unplanned power reductions. On April 24, the plant set up the record of continuous full power operation, which was 310 days in the row.

This current excellent record can be largely accredited to the efforts devoted to training, education and manpower development not only by the utility but also by entities related to nuclear power in Slovenia.

Already at the time when the plant was under construction, and especially during the commissioning also the need and importance of higher education in the area of nuclear engineering was clearly recognised.

Nearly fifteen years ago the Physics Department of the Faculty for Natural Sciences and Technology (now of the Faculty of Mathematics and Physics) at the University of Ljubljana, and the “Jožef Stefan” Institute joined the human resources and initiated the graduate programme in Nuclear Engineering.

At that time the Krško Nuclear Power Plant was going through its initial operational cycles. The vendor predominantly trained plant operational staff. There was no undergraduate programme of nuclear engineering. Only courses on an Introduction to Nuclear Power and Reactors were offered as electives to final year students at the Mechanical and Electrical Engineering Faculties.

This new graduate programme, from its very beginning was intended to remedy this lack of educational opportunities at the university level. Related to nuclear power were: scientific and research activities associated with the 250 KW TRIGA research reactor, safe and reliable operation of the 640 MWe PWR power plant, regulatory supervision of nuclear installations, uranium mine operation, etc.

Since the programme was introduced, the interest for this programme has been steadily growing among regular and evening students. Accordingly, a number of PhD and MS degrees in NE have been awarded. The graduates of this graduate programme have encountered very good job opportunities in nuclear as well as in non-nuclear sector.

2. Graduate programme in nuclear engineering

Over the years the graduate programme in nuclear engineering at the Faculty of Mathematics and Physics has became the focal point of nuclear related, research and educational activities in Slovenia. It has grown into a meeting ground for recognised professor from Slovenian universities, distinguished lectures from foreign educational institutions and experienced professionals from the industry. In conjunction with an important national project, supported by the Slovenian government, entitled “Young Scientists” it also enhances the knowledge transfer to the next generation.

2.1 Programme structure

From the onset, the programme focused on nuclear technology, nuclear safety, and reactor physics and environment protection. According to the charter and the rules of the University of Ljubljana, the programme offers degrees in three levels namely: the Specialist, Master of Science in Nuclear Engineering and the Doctorate in Nuclear Sciences and Engineering.

The curriculum of the graduate programme in Nuclear Engineering takes into account the fact that nuclear engineering covers different professional disciplines. Special emphasis is placed on the knowledge needed to promote further R&D in four main areas:

- Nuclear Technology and Safety.
- Reactor Physics and Core.
- Fuel and Materials.
- Radiology and Radiation Protection.

Class work

The courses are divided into two groups: “the core (mandatory)” and the elective courses. The string of electives is extensive enough to offer wide possibilities, which can be tailored according to the goals, needs and preferences of every individual graduate student. The candidate with the help of his graduate advisor selects courses.

The Master of Science Degree Programme consists of 450 hours of class work and seminars. During the first year all students attend two “core courses” which are prerequisites for all other electives: “Reactor Engineering” and “Mathematics”, jointly consisting of 120 hours. In addition, four elective courses and two seminars supplement the programme.

The elective courses that are offered uniformly cover the four main areas. For clearer insight the complete list of offered electives is in Table 1. The students are also encouraged to select as one of the electives a course that is offered by any other faculty (department) at the University of Ljubljana. This course need not be closely related to nuclear engineering no any other engineering discipline.

Typically the class work for MS degree takes two years.

Seminars and MS thesis

The student's research work takes the form of seminars and the master’s thesis under the guidance of his adviser. Normally it takes place at one of departments of the “Jožef Stefan” Institute. The research related to the thesis is closely liked on the activities of that particular IJS department.

At the beginning of the programme the graduate students start their independent research work, which results in their first seminar. The first seminar mainly focuses on literature search, methodology and basic knowledge essential for subsequent research. The second seminar is supplementary to the first one and usually integrates the specific topics, which are broadly covered in the elective courses.

The master’s thesis has to be submitted to fulfil all requirements for graduation. Seminars and research work for the thesis normally deals with up to date issues related to the use of nuclear energy and in particular with the upgrading of safety. Results from research completed by the student while preparing his MS thesis have been successfully presented at important international and domestic conferences. Some results have even been published in international journals.

Table 1. **List of elective courses**

Ecology	Fracture Mechanics
Engineering Materials	Fuel Burn up and Management
Fuel Cycle Chemistry	Fuel and Nuclear Materials
Heat Transfer	Mathematical Process Modelling
Materials Radiation Damage	Modelling in Nuclear Technology
Neutrons Transport Theory	Nuclear Power Plants Measurements
Nuclear Facilities Environmental Impact	Nuclear Engineering Analysis and Methods
Nuclear Fuel Technology	Nuclear Waste Reprocessing and Disposal
Nuclear Power Plant Technology	Probabilistic Safety Assessment
Radioactive Substances in Ecosystems	Reactor Operation Physics
Radiology and Radiation Protection	Reactor Control and Instrumentation
Reactor Physics	Reactor Kinetic
Reactor Engineering Materials	Reactor Core Design Evaluation
Safety and Reliability of Nuclear Facilities	Structural Mechanics
Biological Indicators and Dose Estimate	Thermodynamics Process Safety Analysis
Chemistry and Analysis of Radio-nuclides	Uranium Chemistry and Technology
Fluid Mechanics	Use of Radioactive Isotopes

PhD degree

After completion of the Master of Science programme the candidates can continue their academic studies on the doctorate level. At this level the student concentrates on supervised but independent research. Normally it takes at least two years before he can successfully defend dissertation and obtain the Ph.D. Degree. It is by the rule expected that he publish a paper dealing with his research in an international journal before being admitted to the public defence of his dissertation.

3. Enrolment

Since the commencement of the programme 47 students entered the graduate programme in Nuclear Engineering. A number (28) of graduate students have successfully completed their MS studies. In addition eight Ph.D. Degrees have been awarded. The titles of theses, which have been submitted and successfully defended, are listed in Table 2.

It is important to note that besides candidates that are financially supported by the government in the framework of the programme called “Young Scientists” more and more often the programme is raising interest among professionals who are already employed by organisation or companies dealing with nuclear energy. So the students enrolling in NE graduate programme also come from the Krško Nuclear Power Plant, from the Slovene Nuclear Safety Administration and Slovenian Agency for Radioactive Waste.

All graduates who have received their degrees from this graduate programme have taken up important duties and responsibilities in institutions engaged in the Slovene nuclear programme. So far the students have shown particular interest for classed related to reactor technology in reactor core physics.

Recent indications are that, due to increased interest in environmental issues, the area of Radiology and Radiation Protection will attract more students. The overall experience has proven that the programme is well structured and justified. The programme is also becoming internationally known. Its quality as can be judged by increasing interest in academic circles and student inquiries about the possibilities of enrolment from abroad.

More than twenty distinguished professors from numerous faculties from Ljubljana and Maribor universities and recognised scientists from “J. Stefan” Institute participate in the graduate programme in Nuclear Engineering. Each year also a number of foreign professors take part in this programme as lecturers.

Slovenian needs for graduate engineers, master’s degree holders and PhDs in Nuclear Engineering is substantial. With the exception of the Krško NPP hardly any other institution associated with the nuclear programme has reached its critical mass.

An estimate of the employment needs for such personnel was made for the period of the last five years. It showed, that the main demand for such personnel is at the Krško Nuclear Power Plant, the Slovene Nuclear Safety Administration and of course at the “Jožef Stefan” Institute together with its Nuclear Training Centre. Some companies, institutes and national institutions are also interested in them.

The graduates are well received wherever they seek employment. Not only in entities associated directly with nuclear power, the knowledge accumulated by the students, can also be applied in other “non-nuclear” areas, advanced modelling techniques and familiarity with modern computer systems are prerequisites for success in any modern industry.

4. Discussion

The assumption, that nuclear energy will contribute a considerable part in electricity production also in the 21st century, can be considered still valid. In the competitive and deregulated energy market, it is imperative that the importance of higher education and research in nuclear engineering is not overlooked. At this time signs that the human resources may become the limiting factor for further safe and reliable nuclear energy utilisation are still rather weak. The time constants associated with manpower development on the other hand are rather long. They become even longer if no effort is made on time.

Where current educators have vested interest the level and quality is still growing, on the other hand the quantity in many cases is gradually decreasing. Lessons that have been learned to give positive results on the graduate level may be summarised as follows:

- the current and most likely subsequent generations of students are increasingly interested in education,
- the “normal inflow of students” into the nuclear arena is diminishing, to reach the proper balance additional motivation may give positive changes,
- Independent (guided, streamlined) research of the student, who becomes and works as part of the well-established research team definitely gives better results and shortens the time needed.
- Early exposure to and lively response of the “real nuclear world” helps the student define and articulate his goals for the future,
- The ERASMUS objectives should be closely examined and taken up by the nuclear community.

5. Conclusions

From the experience of the past fifteen years we can draw a number of conclusions:

1. Efforts put into establishing this Nuclear Engineering graduate programme at the Faculty of Mathematics and Physics of the University of Ljubljana were well justified.

2. Graduates of the Nuclear Engineering Masters and PhD programmes have excellent employment possibilities and opportunities not only in nuclear arena but also in other area that are dealing with advanced computer technologies.

3. The knowledge and capabilities acquired by graduate students of Nuclear Engineering can be well applied in other engineering assignments.

4. International links and co-operation with related universities should continue, mobility of teachers should be strengthened.

5. Offering appropriate possibilities, infrastructure and scientific environment is a prerequisite for successful motivation of students to pursue the nuclear path.

6. International mobility of students and cross-university recognition of credits may preserve wide variety of specialists.

7. The positive experience accumulated and problems encountered indicate that an appropriate solution for an undergraduate nuclear engineering programme should be found as soon as possible.

Table 2. **Theses in the last 10 years**

Ph.D. degrees:

1993 On the Estimation of the Steam Generator Maintenance Efficiency by the Means of Probabilistic Fracture Mechanics, Cizelj.

1996 Validation of Theoretical Models of Pulse Parameter in TRIGA Reactor; Mele.

1997 Second Order Accurate Schemes for Two-fluid Models of Two-phase Flow; Tiselj.

1998 Nuclear Power Plant Transient Diagnostics Using Methods Based on the Status of Balanced Systems; Šalamun.

1998 Monte Carlo Calculation of Neutrons and Photons Transport in Complex Geometry; Maucec

1999 Uncertainty Quantification of Best Estimate Computer Code Predictions of Accidents in Nuclear Power Plants; Prošek.

1999 Improvement of Computerised Safety-Related Systems Reliability in Nuclear Power Plants; Cepin.

Master degrees:

1989 Dynamic Model and Simulation of PWR Coolant System; Jure Marn.

1989 Analysis of Dynamically Excited Piping Systems Using Multiple Response Spectra and Finite Elements Method; Leon Cizelj.

1991 Safety Aspects of Thermal Hydraulic Characteristics of PWR Core; Venceslav Kostadinov.

1992 PSA for NPP – Optimisation of Instrument Air System Availability; Mitja Kožuh.

1992 Non-equilibrium Process During Loss of Coolant Accidents in NPP; Iztok Parzer.

1992 Application of CAU Methodology for Large Break Loss of Coolant Accident in NPP; Prošek.

1993 Development and Review of Computational Procedures of Reactor Core Design; Železnik.

1993 PWR Fuel Element Homogenisation; Iztok Svetin.

1993 Critical Discharge and Small Break Loss of Coolant Accident in NPP; Oton Gortnar.

1994 The Estimation of Frequency of Research Reactor Releases with Probabilistic Safety Assessment; Jordan Romana.

1994 Modelling of the Critical Flashing Flow in the Nozzle; Tiselj Iztok.

1995 Digital Systems as Operator Support in Management of Nuclear Power Plant During Emergency Conditions; Salamun Igor.

1995 Technical Specification Optimization in Nuclear Power Plant Based on Probabilistic Safety Assessment; Cepin Marko.

1996 Comparison of Maintenance Strategies Applied to Steam Generator Tubes; Dvorsek Tomaz.

1996 Two-dimensional Calculation of a Research Reactor; Persic Andrejka.

1996 Multiphase Fluid Mixing Model; Leskovar Matjaz.

1997 Safety Importance Determination of Design Changes in Nuclear Installations; Kranjc Bozidar.

1997 Procedure for Fast Prediction of Radiation Doses; Breznik Borut.

1997 Probabilistic Model of Excessive Leakage; Hauer Irena.

1998 Animation of Severe Accident Analyzer for Nuclear Power Plant; Maselj Andrej.

1998 Results from Scaled-Down Experimental Facility to Nuclear Power Plant; Ravnikar Igor.

1998 Modelling of Two-Fluid Flow with Interface; Gregor Cerne.

1998 Modelling of Natural Convection Phenomena in Nuclear Reactor Core Melt; Andrej Horvat.

1998 Calculation of Activity and Decay Heat of NPP Krsko Spent Fuel; Matjaz Bozic.

1999 Monte Carlo Calculations for in Situ Gamma Measurements; Gregor Omahen.

1999 Modelling of the Subcooled Flow Boiling; Bostjan Koncar.

1999 Derivation and Verification of Nuclear Constants for Activation Analysis Obtained From Evaluated Nuclear Data Libraries; Radojko Jacimovic.

DISSEMINATION OF OPPORTUNITIES IN NUCLEAR SCIENCE AND TECHNOLOGY IN MEXICO

G. S. Alcocer Gómez
Comisión Nacional de Seguridad Nuclear y Salvaguardias
Dr. Barragin No. 779, Col. Narvarte
Del. Benito Juárez. C. P. 03020. Mdxico, D. F. MEXICO
cnsns1@servidor.unam.mx

Abstract

Nowadays, activities in the fields of nuclear science are increasing in Mexico. Notwithstanding the existence of just one nuclear power plant in the country, the Laguna Verde Nuclear Power Station, young people (ages from 18 to 25) show a significant interest in areas such as environmental protection, nuclear safety, nuclear regulation, food irradiation, materials science, medical and industrial uses of ionising radiation, but this interest is heterogeneous and poorly grounded.

Several schools provide formation of professionals in Physics, Chemistry, and Engineering. On the other hand, there are research institutes dedicated to specialised industrial activities which provide post-graduate courses and specific training in nuclear technology and related fields, and in radiation protection.

However, there is a lack of a proper bond between schools and research institutes, and young people. Must of the students without a career orientation simply make their choice considering geographic and economic aspects. This kind of student is the focus of our interest in constructing the required proper bond between young people and nuclear technology.

This paper evaluates the concept of a fair-festival event, and examines the possibility of it's use to promote the nuclear field in Mexico. Other current dissemination activities are considered too.

1. Introduction

Activities in the fields of nuclear science and technology and in radiation protection, are increasing in Mexico. Young people (ages from 18 to 25) show a significant interest in areas such as environmental protection, nuclear safety, nuclear regulation, food irradiation, materials science, medical and industrial uses of ionising radiation, etcetera, but this interest is heterogeneous and poorly grounded.

Several schools consider the academic formation of professionals in Physics, Chemistry, and Engineering; the Universidad Nacional Autónoma de Mexico, (National Autonomous University of Mexico), the Instituto Politécnico Nacional (National Polytechnic Institute), the Universidad Autónoma Metropolitana (Autonomous Metropolitan University), and the Universidad de Zacatecas (Zacatecas State University), are some of the most important institutions that provide degree courses in nuclear physics, nuclear engineering, nuclear chemistry, and other related subjects.

On the other hand, there are research institutes dedicated to specialised industrial activities, such as the Instituto Nacional de Investigaciones Nucleares (National Institute for Nuclear Research), the Instituto Mexicano del Petroleo (Mexican Petroleum Institute), and the Instituto de Investigaciones Eléctricas (Electric Research Institute), which provide postgraduate courses and specific training in nuclear technology and related fields, and in radiation protection. Moreover, it is necessary to mention the research activities of institutes attached to the schools listed above, in which theoretical aspects of nuclear science are regarded.

However, there is a lack of a proper bond between these educational and research institutes, and young people. Potential students of nuclear science matters generally make their career selection carefully, taking into account the curricula provided by schools, but students without a career orientation simply make their choice considering geographic and economic aspects. This last kind of student is the focus of our interest in constructing the required proper bond between young people and nuclear technology.

To overcome this situation, each school implements different strategies, performing diffusion activities as follows:

- preparation and distribution of brochures about careers and courses, but such documents have a limited distribution (only in school specific installations); consequently, the information presented in these brochures reaches few people;
- installation of a web page including careers and schedules of courses; the information presented sometimes is incomplete with respect to curricula; because of the costs of Internet connections, a limited number of students can browse these pages;
- brief presentations of curricula, schedules and campi, performed at campus auditorium on defined dates; and
- conferences and exhibitions on general and specific matters.

Similar to previous activities (a) and (b), research institutions prepare brochures and web pages with curricula, schedules, teaching staff and costs information, which is addressed to post-graduate students.

The above mentioned activities are executed in a non-systematic/non-integrated approach, therefore producing heterogeneous results with respect to the dissemination of information.

Considering these circumstances, recently the Universidad Nacional Autónoma de México has started an annual global. exhibition of career profiles and professional opportunities, a fair – festival event called “Al Encuentro del Mañana” (Onward Tomorrow), that includes public and private schools, commercial and industrial enterprises, research. institutions and governmental organisations. The purpose of this exhibition is to present in a logical sequence and in one place, general information about universities, – technical and technological institutions, and job opportunities to young people who are in the process of a career selection.

2. Actual Activities

2.1 Al Encuentro del Mañana (Onward Tomorrow) fair-festival

This vocational orientation exhibition is organised by the Universidad Nacional Autónoma de México (National Autonomous University of Mexico), through the Secretaria de Asuntos Estudiantiles (Students Affairs Secretariat).

The aim of this exhibition is to support the students in the selection of a career, providing them with proper information about professional profiles and education options available in Mexico City - and surroundings.

This exhibition is displayed over three thousand square meters, integrating six main areas:

- Mexican Professional Education System.
- Professional Studies.
- Educational Orientation Services.
- Professional Opportunities.
- Commercial Zone.
- Artistic and Cultural Activities.

The last version of this exhibition, celebrated in October of 1998, was visited by seventy thousand registered people approximately, plus an undefined number of visitors (about 35 000 estimated); this result is remarkably good, considering that one hundred thousand was the expected figure.

The organisation committee is integrated also by schools and faculties of several fields, including basic sciences, engineering, social and economic disciplines, medical and biological sciences, and so forth. In consequence, these promotion activities are generic.

Considering professional opportunities, several public and private organisations are represented. Such entities include a very wide range of activities, from services and commercial jobs to technological and scientific profiles.

The most of visitors come from Mexico City and surroundings; they arrive without properly defined career expectations. Although the purpose of this fair-festival is to provide basic information to the potential student about career selection, the corresponding orientation effort of the Educational

Orientation Services is sometimes diluted, due to the lack of perspective shown, by very young visitors – (ages from 15 to 18 years).

On the other hand, some students at the Bachelor of Sciences level, coming from public universities in the main, are seeking for opportunities in post-graduate studies; the area of Educational Orientation Services of the exhibition provides brochures and specific information about courses and schedules, and several private universities grant on-line access to web pages and compact disc interactive presentations.

In the context of Professional Opportunities, and considering specifically the energy field, the entities represented in the last version of this fair-festival were:

- The Instituto Nacional de Investigaciones Nucleares (National Institute for Nuclear Research), which contributes to the scientific and technological research in the fields of nuclear energy, environmental protection and metrology of ionising radiation.
- The Comisión Nacional para el Ahorro de Energia (National Commission for Energy Saving), a specialiscd inter-institutional organisation that promotes improvements on energy consumption and efficiency.
- The Comisión Reguladora de la Energia (Regulatory Energy Commission), the gas and electricity national regulatory body.
- The Comisión Federal de Electricidad (Federal Electricity Commission), the state-owned national utility for electric power generation, transmission and distribution.
- The Comisión Nacional de Seguridad Nuclear y Salvaguardias (National Commission on Nuclear Safety and Safeguards), the Mexican nuclear regulatory body.

All these bodies were located in two stands; their effort in the dissemination of job opportunities and professional development consisted in:

- Brochure distribution (15 000 brochures approximately).
- Interactive CD and computer presentations.
- Web page presentations.
- Video presentations.
- Individual and group general and specific explanations.

The book of visitors of these stands was signed by more than five hundred visitors. Valuable remarks and suggestions were received, and will be accounted in section 4 of this paper.

2.2 Professional Societies Activities

There are two professional societies directly related with nuclear science and technology in Mexico: the Sociedad Mexicana de Seguridad Radiológica (Mexican Health Physics Society), and the Sociedad Nuclear Mexicana (Mexican Nuclear Society).

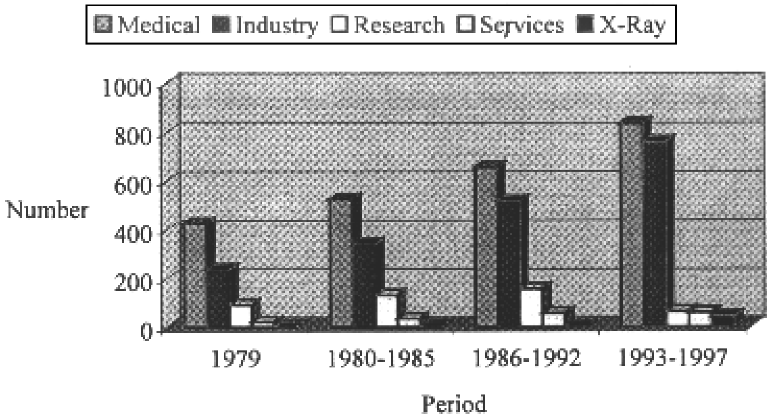
Through conferences and pre-congress courses, both societies perform dissemination activities, addressed to technical audiences and students. Such activities include poster presentations, topical specific courses, and magisterial conferences. Due to budget, space and time limitations, these activities actually cannot to be extended to young people.

3. Identified requirements

3.1 Manpower Demand in Mexico

Figure 1 shows the number of users of radioactive material with respect to several fields of application in Mexico.

Fig. 1. Users of Radioactive Material



This growing trend in non-nuclear activities requires the subsequent training of specialised staff, in practical and theoretical aspects.

With respect to nuclear activities, manpower requirements are satisfied (by now) in electric generation by nuclear power means, but several areas such as waste management, radioactive materials transportation, fuel cycle tasks, nuclear instrumentation and so forth, are still waiting for properly trained staff.

3.2 Education and training perspectives

In Mexico, few educational institutions provide teaching in the' nuclear field topics; these are the following:

- Instituto Politécnico Nacional (IPN).
- Universidad Nacional Autónoma de México (UNAM).
- Universidad Autónoma Metropolitana (UAM).
- Universidad Autónoma de Zacatecas – Centro Regional de Estudios Nucleares (UAZ-CREN).

However, the activities in such educational organisations has been depressed. The oldest programme in nuclear engineering at a Master in Sciences level is offered by the Nuclear Engineering Department of the National Polytechnic Institute (IPN-ESF-DIN). Because of the lack of governmental sponsorship to this programme, it is highly probable that it's end is near.

Other educational programmes have been cancelled or restructured. The original programme of UNAM was a Master in Nuclear Sciences with three options: Nuclear Engineering, Nuclear Fuel and Nuclear Chemistry, but it was substituted by Master and PhD programmes in Nuclear Chemistry only. The subjects of nuclear engineering and nuclear reactors vanished. The Universidad Autónoma Metropolitana (Metropolitan Autonomous University), offers teaching in general energy topics (Iztapalapa campus), and fundamental nuclear engineering subjects (Azcapotzalco campus), but the number of students in then nuclear field is lower every day. The programme that UAZ-CREN offers includes Nuclear Engineering, Nuclear Medicine, Nuclear Electronics and Nuclear Measurements. This programme started in 1995, but actually the number of students is very small (about two students per year in nuclear engineering and nuclear electronics).

Considering the above mentioned, the future of education in the nuclear field is uncertain in Mexico, and taking into account the growing trends in manpower requirements shown by industrial and medical uses of ionising radiation, and the unresolved pending matters of waste management and radioactive materials transportation, the breach between the required staff and available staff will increase in the near future.

The organisations directly affected by this situation are facing the problem through specific local training courses, and implementing an "on the job training" strategy, trying to provide the required basic skills to their staff.

4. Possible future activities

It is evident that a new approach is required, taking into account the growing trends in medical and industrial uses of ionising radiation, and unresolved matters.

The book of visitors mentioned in the last paragraph of section 2.1 of this paper, give us some idea about how to face this problem. Areas that deserve special attention are:

- Opportune and appropriate vocational orientation addressed to young people.
- Extensive dissemination of job opportunities in the nuclear field, addressed to students that are in the process of a career selection.
- Co-ordinated efforts between schools and users of radioactive materials and ionising radiation, to met the required linking among academic activities and practical tasks.
- Promotion of the safe utilisation of ionising radiation via dissemination of the national and international regulatory frames.
- Dissemination of technological innovations in the nuclear field.

Such areas require an integrated approach to receive proper attention. Adequate allocation of human, material and financial resources must be implemented to overcome the lack of bond between young people, educational organisations, research institutions and job opportunities.

5. Conclusions

"Al Encuentro del Mañana" (Onward Tomorrow) fair-festival is the first effort specifically addressed to young people, that focuses the above mentioned areas with an integrated and systematic approach.

However, more events of this scope are required in the country, taking into account particular needs and specific characteristics of each region.

In the case of assuring Nuclear Safety Competence,, the state-owned utility has a local training programme, providing in that way the basic skills to operations and maintenance staff. This programme is evaluated by the CNSNS, the Mexican Regulatory Body, through the regulatory frame in force.

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THE ROLE OF INTERNATIONAL ATOMIC ENERGY AGENCY IN MAINTAINING NUCLEAR SAFETY COMPETENCE

Ilari Aro and Thomas Mazour
International Atomic Energy Agency
Department of Nuclear Safety/ Department of Nuclear Energy
Wagramerstrasse 5, P.O. 100,
A-1400 Vienna, Austria
I.Aro@iaea.org, T.Mazour@iaea.org

Abstract

This paper provides information how International Atomic Energy Agency can assist Member States in maintaining and developing nuclear safety competence. The topics covered include the development of safety standards, organisation of nuclear safety related conferences, provision of safety reviews, organisation of training courses and topical workshops and publication of training related documents. Usefulness of these activities for competence development is discussed.

1. Introduction

When we speak about competence we normally think of individuals. For them competence means the experience, knowledge, skills and professional attitudes to perform a certain job and specific tasks. One can also take an organisational point of view when dealing with competence. If an organisation is continually involved in certain activities it normally has a proper organisational setting, established working methods and standards as well as organisational and quality manuals where these activities are defined and described. Designs are documented and experiences are reported. There are established training programmes to train new staff members and for learning from the past experience. With these methods the organisation is able to transfer information to its new staff who will be performing activities for the first time. If these methods are lacking and the organisation loses its experienced staff members, the organisation may also lose its competence to perform certain activities. Good example cases of rare activities to be considered in this respect are a project to modernize an old nuclear power plant or to plan the decommissioning of a nuclear power plant.

Maintaining and developing competence requires a constant follow-up of international and national developments in practices, standards, technology and research results as well as operating experience. International exchange of information is an important element in addition to the internal continuing training programmes of organisations.

2. The role of IAEA

How can the International Atomic Energy Agency assist the Member States in maintaining and developing competence? The IAEA has certain activities and programmes which are very useful for the Member Sates in this respect. And it is not only the results of these activities that are useful, but also the participation in their development and implementation. In the following, some of the IAEA activities are described and recent participation from NEA countries is highlighted.

One of the main functions of the IAEA is standards development. The development of nuclear, radiation and waste safety requirements and safety guides (standards) provides up-to-date information on internationally approved safety levels and their development. The standards provide a good reference for organisations and individuals for comparison and for identifying topics for development. There are committees responsible for the development of safety standards such as ACSS, NUSSAC, RASSAC and WASSAC. The members of these committees and participants in consultants' meetings developing these standards and practices get a good view of the latest international developments in safety. Thus participating organisations benefit from these activities also in the form of an increase in competence. Table 1 shows the extent of NEA participation in these activities. The IAEA has published several safety standards and reports concerning the competence of staff working in the nuclear safety field e.g. Safety Guides on staffing and training in the regulatory organisations (50-SG-G1, under revision) and in NPP operating organisations (50-SG-O1, under revision) as well as Technical Report Series No. 380 on Systematic Approach to Training (SAT) methodology.

A complementary function of the IAEA is to provide for the application of the safety standards. One of the major roles of the IAEA is to organize meetings and conferences to exchange information and to develop specific reports and practices. These meetings and conferences provide possibilities to get new ideas, learn how these ideas have been implemented in some countries and thus to get new information on how to develop one's own practices. Such meetings and conferences are important tools for maintaining and developing competence. (See Table 1) Another mechanism to provide for the application of standards is the services which the IAEA offers, e.g. the following activities:

- OSART – and ASSET-missions meant for nuclear power plant organisations to review their operating organisation and operational experience feedback;
- siting and design reviews to assist Member States in considering whether there are needs for upgrading or modernization of NPPs;
- IRRT missions to review regulatory activities.

These services are widely used by the Member States. Table 1 shows the number of missions organized, the number of missions invited by the NEA countries and the number of participating experts from the NEA countries. For organisations these missions provide a possibility to compare organisational practices and to get new ideas on up-to-date practices. These kind of missions also provide the best means of transferring knowledge and skills between participating experts. Therefore they also provide excellent means to maintain and develop competence for organisations and participating individuals. A limited number of observers also participate in the missions. With these programmes the IAEA is an important contributor in provision of information exchange possibilities.

Table 1. IAEA Activities: Experts Participation from OECD Countries

	Total number of activities	Organised in OECD countries	Number of participants	Number of experts from OECD countries
Safety Standards and Advisory committees	about 8/year	–	110	60
Safety related conferences and meetings 1996-98	About 30/year	–	–	about 1400
Safety missions 1996-98				
OSART missions	about 30	15	–	80
ASSET missions	about 40	11	–	35
Siting/Design reviews	about 30	4	–	–
IRRT missions	about 10	1	–	20
Training courses and Workshops 1997-99	65	26	about 1200	about 200

2.1. IAEA's training courses on nuclear safety

IAEA is also an important training organisation and it co-operates with the relevant organisations in Member States for offering and developing training courses and specific workshops mainly for the countries in receipt of assistance from the IAEA. Major organisations with a long standing tradition assisting the IAEA in this respect are ANL (Argonne) in the USA, Forschungszentrum Karlsruhe in Germany and INSTN (CEA) in Saclay (Paris) in France. There are also other important contributors in the field of nuclear safety. In most cases, the trainers are recruited from the NEA countries. In this field the Agency is now developing its services to offer more standardized quality training courses, which are fully applicable in the NEA countries, too. In co-operation with the above organisations the IAEA is now developing a set of general and specific training courses including syllabi, example programmes and written learning materials including text books to be used also by the Member States. The development of these will take some years. The existing training materials have been collected in a small training library in the IAEA. The IAEA will make them available to training planners from the Member States. One of the major efforts in addition to the definition of course contents and programmes is the development of text books. These books can then also be used by the Member States organisations in their internal training activities.

The preliminary draft for the training courses (nuclear safety) have been developed on the basis of the IAEA training courses and specific workshops during the period 1997-99 (see Figure 1 and Table 2). A set of training courses and specific modules will be finalized during 1999. One of the first standardized training courses is the Basic Professional Training Course on Nuclear Safety which is an educational course meant for the beginners, who are expected to be professionals, currently employed by regulatory bodies, reactor operating organisations and technical support organisations. They will be expected to fit the following criteria: Have at least a first university degree in engineering or science related to nuclear technology; Have two or three years of successful professional experience beyond university; Be in a first or second level position with positive potential; Be judged by supervisors to have the potential to rise in the organisation and to act as a mentor of more junior staff; Be capable of passing the information gained in the course to others in the home country; Possess the interpersonal skills and language skills necessary to participate effectively in a multi-country learning experience. The length of the standard training course is nine weeks, containing 22 separate modules covering the most important nuclear safety related issues. The course will be organized for the first time from 4 October to 3 December 1999 in Saclay, France, in co-operation with IAEA and INSTN (CEA). The length of the text book is planned to be about 1 000 pages.

As can be seen in Fig. 1 the next step of training courses is specialized courses or modules to support the training of those who have already selected their career and who are more experienced in their field of expertise. One of the examples of these courses is Regulatory Control of Nuclear Power Plants which is meant for professional staff members of the nuclear safety regulatory body supervising NPPs and having duties in the regulatory fields. The length of the standard training course is two weeks. The course has been organized six times in Europe: Slovak Republic, Finland, Germany (twice), Czech Republic, UK, and twice in Asia: in the Republic of Korea and Indonesia during the period 1994-1999. The length of the text book is 270 pages.

Training courses organized through the Department of Technical Co-operation's programmes give priority to participants from developing Member States. However, candidates from developed Member States can be considered on merit, often attending in an observer capacity.

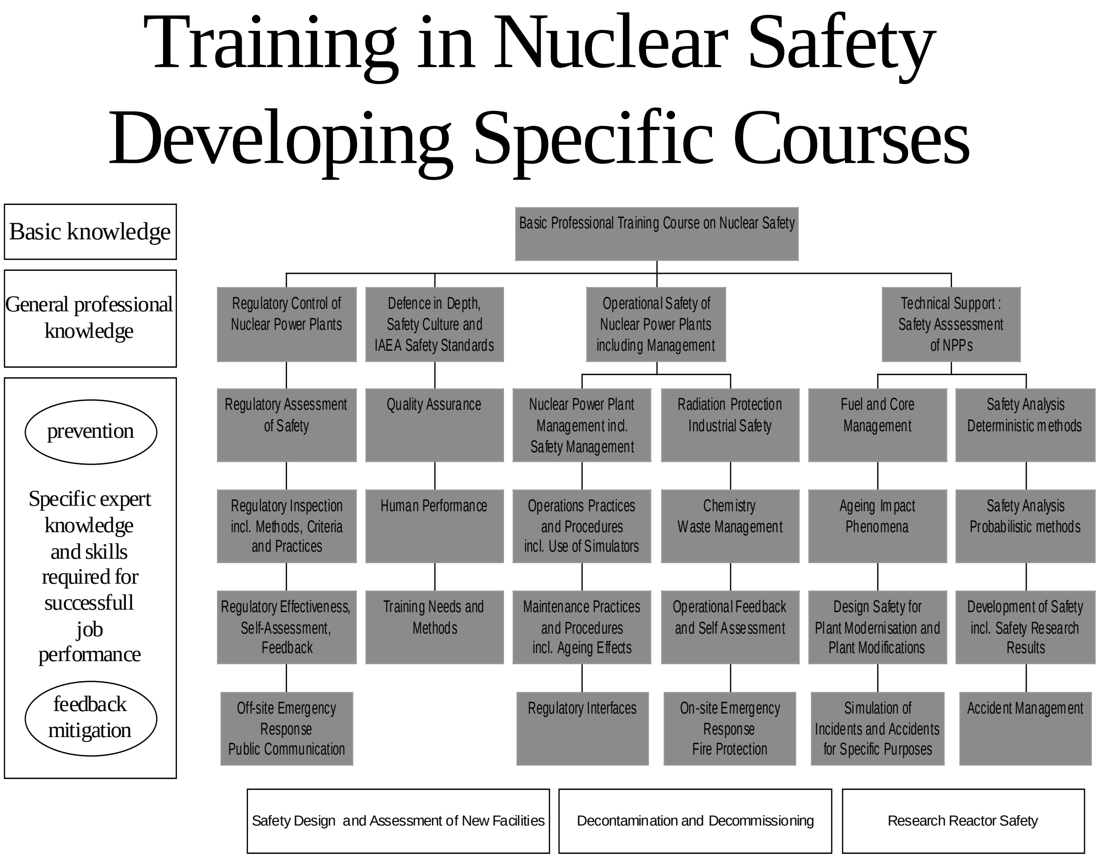

Figure 1. **A draft proposal: training in nuclear safety – developing specific courses**

The next step in the activities is to develop and standardize the contents of Basic Professional Training Course on Nuclear Safety and the four general courses for the regulatory, nuclear power plant management and technical support staff as well as a specific course on nuclear safety. This also includes the development of text books for the courses and preferably the selection of key overheads to be used by the instructors in addition to their own selection. The intention is also to provide these materials to the Member States organisations to support their own training activities. These courses could then be offered regularly by the IAEA for the Member States to provide training for the new staff members. The periodicity could then depend on the needs of the Member States entitled to get assistance from the IAEA. Another solution is that certain organisations could offer these training courses on commercial basis to all countries needing training services to train their new staff members. An effort has been started to translate the text book of Basic Professional Training Course on Nuclear Safety into Russian.

The specific training courses or workshops are meant for more experienced staff members and the content could depend on the topical needs of the Member States. The standardized training materials, however, could be used to provide some basic part of these events to increase the quality. Some of the topics might be such that a standardized training course could be develop for them.

2.2 IAEA publications regarding training and qualification of NPP personnel

The IAEA has an ongoing project to develop technical documents that provide guidance and lessons learned regarding the training and qualification of NPP personnel. Provided below is a summary of existing documents, as well as a description of documents that are currently under development:

General, including SAT guidance

- Safety Guide: Recruitment, Qualification, Training and Authorization of NPP Personnel [in draft; to supersede 50-SG-01 (Rev.1)]
- Nuclear Power Plant Personnel Training And Its Evaluation: A Guidebook, Technical Reports Series (TRS) No. 380 (1996)
- Experience in the Use of the Systematic Approach to Training for Nuclear Power Plant Personnel, IAEA-TECDOC-1057 (1998)
- IAEA World Survey of Nuclear Power Plant Personnel Training, IAEA-TECDOC-1063 (1999)
- Engineering and Science Education for Nuclear Power: A Guidebook TRS No. 266 (1989)
- Manpower Development for Nuclear Power, TRS No. 200 (1980)
- Measuring the Effectiveness of Training Programmes for NPP Personnel (document under preparation; to be available in 2000)
- Information Management for SAT applications (document under preparation; to be available in 2000)
- Assuring the Competence of NPP Contractor Personnel (document under preparation; to be available in 2000)

Use of simulators for training of NPP personnel

- Selection , Specification, Design and Use of Various Nuclear Power Plant Training Simulators, IAEA-TECDOC-995 (1998)
- Simulators for Training Nuclear Power Plant Personnel, IAEA-TECDOC 685 (1993)
- Common Modelling Approaches for Training Simulators for Nuclear Power Plants, IAEA-TECDOC 546 (1990)

Other NPP personnel training topics

- Selection, Competency Development and Assessment of Nuclear Power Plant Managers, IAEATECDOC-1024 (1998)
- Guidebook on the Education and Training of Technicians for Nuclear Power, TRS No. 306 (1986)
- Manual on Training, Qualification and Certification of Quality Assurance Personnel, TRS No. 262 (1989)

2.3 IAEA international working group on nuclear power plant personnel training and qualification (IWG-T&Q)

The IWG-T&Q was established in 1994 to provide the Director General of the IAEA with advice and opinions on the Agency's current and future activities related to establishing, maintaining and enhancing the competence of nuclear power plant personnel, as well as to:

- Provide Member States with information, recommendations and advice on all aspects of nuclear power plant personnel training and qualification with the aim of enhancing the safe, reliable and economic operation of the plant.
- Promote exchange of information on national programmes, new developments and experience from operating nuclear power plants and training centres, and the co-ordination of studies and reviews on all aspects of nuclear power plant personnel training and qualification.
- Promote the effective implementation of relevant IAEA Standards, Guides and other documents at the nuclear power plant level through training programmes and related activities.

The IWG-T&Q has members from all of the IAEA (and NEA) Member States that have nuclear power plants in operation. It has served as a very cost effective mechanism to achieve the above objectives.

3. Conclusions

IAEA has an important role in maintaining nuclear safety competence in the Member States. This work has been channeled through nuclear safety standards programme, Agency's safety services programme, through organizing conferences and seminars on topical matters and through publishing useful training related documents. To improve its services for training new staff members in the Member States' organisations in nuclear safety and specifically in application of Agency's safety standards IAEA is developing Basic Professional Training Courses on Nuclear Safety. These courses can then be offered to the Member States regularly in addition to the provision of training materials which can be used by the Member States by themselves.

Table 2. **IAEA training courses and workshops (nuclear safety) in 1997-1999**

1997

Interregional Training Course on Assessment of Operational Safety Performance of NPPs (USA)

Interregional Training Course on Prevention and Management of Accidents in NPPs (USA, Canada)

Interregional Training Course on Managing Safety Aspects on NPP Ageing through Effective Operation, Inspection, Monitoring and Maintenance (Canada; USA)

Regional Training Course on Regulatory Control of NPPs (Czech Republic)

Regional (AFRA) Training Course on PSA and Accident Analysis (South Africa)

Regional Management Workshop I – on Good Operational Safety Management (Vienna)

Regional Workshop on Reliability Data base for PSA (Slovak Republic)

Regional Workshop on Codes and Methods of Accident Analysis (Russia)

Regional Workshop on Safety Analysis of Plant Modification (Slovenia)

Regional Workshop on Review of Accident Analysis for Emergency Operating Procedures (Slovenia)

Regional Workshop for Utilities on Periodic Safety Review of NPPs (Czech Republic)

Regional Training Course on Inspection Techniques (Slovenia)

Regional Regulatory Training Workshop on Periodic Safety Review of NPP (Hungary)

Regional Workshop on Review of Incidents (Czech Republic)

Regional Training Workshop on Operator Training and Licensing (Finland)

1998

Interregional Training Course on Operator Regulator Interface for NPPs (USA)

Interregional Training Course on Advances in monitoring, assessment and enhancement of operational safety oh NPP’s (USA)

Interregional Training Course on Regulatory aspects of safety documentation of research reactors (USA)

Regional Training Course on Safety in the operation of research reactors for operators (Czech Republic)

1998 (cont.)

Regional Training Course on Safety of Nuclear Installations (China/ Korea)

Regional Workshop on Human Factors in Nuclear Safety (Slovenia)

Modelling of External Hazards in PSA (Russia)

Format and Content of SAR (Bulgaria)

Safety Analysis of Plant Modifications (Slovenia)

Analytical Methods and Computational Tools for NPP Safety Assessment (Russia)

Application of Plant Simulators and Analysis for Validating EOP’s (Romania)

Monitoring Operational Performance through Operating Experience (Czech Rebublic)

Operational Safety Performance Indicators (Slovenia)

Severe Accident Management (Slovenia)

Regional Training Course on Regulatory Control of NPP’s (Germany)

Regional Workshop on Regulatory Review of Plant SAR (Slovak Republic)

Regional Workshop on Regulatory Use of PSA Methods (Finland)

Radiation Protection Issues in NPPs (Slovenia)

Establishment of Training Programmes for the Regulatory Staff (Finland)

Decommissioning (Slovenia)

Train the Trainers in Nuclear Safety (Republic of Korea)

Operating Organisation and Self-Assessment of Safety Culture (Republic of Korea)

Operating Experience Feedback (China)

Management Workshop on Operational and Safety Issues of NPP’s (China)

Definition and Maintenance of Safe Operating Envelope (Canada)

Operational Experience Feedback and Self-Assessment of Operational Safety (Pakistan)

Maintenance Optimization (India)

Table 2. **IAEA training courses and workshops (nuclear safety) in 1997-1999, cont.**

1999

Interregional Training Course on Environmental Qualification of Equipment important to safety in NPP's (Spain)

Regional Training Course on Regulatory Control of NPP's (UK)

Regional Training Course: Basic Professional Training Course on Nuclear Safety (France)

Regional Training Course on Train the Trainers in Nuclear Safety, including the Use of Basic Simulators for Training of NPP Technical Personnel (Slovenia)

Advanced Training Course on PSA Modelling Techniques, including HRA, CCF, Level 2 Shutdown PSA and an overview of PSA Applications (Spain)

Joint Utility/Regulatory Benefits of Periodic Safety Reviews (Hungary)

Safety Assessment of Plant Modifications with Emphasis on I & C Modernization and Human Machine Interface Issues (Slovenia)

Development and validation of EOPs for Effective Prevention/Mitigation of Severe Core Damage (Slovak Republic)

NPP Operating Cycle Extension (On-line Maintenance, Maintenance Optimization, ISI, TS Applicability (Slovenia)

Safety Issues for RBMKs (Lithuania)

Application of Selected Event Analysis Methodologies to Actual Events from NPPs (Slovak Republic)

Forum of safety analysis for WWER and RBMK (Russia)

Utility Regulatory Interface for NPP Safety (Germany)

Management of Safety and Safety Culture (Bulgaria)

Enhancement of Operational Safety (Slovenia)

1999 (cont.)

Regulatory experience in introducing advanced computer based technology into safety systems at nuclear power plants (Slovenia)

Regulatory review of licensee safety performance (Spain)

Workshop on Licensing of Modifications (Slovenia)

Workshop on Co-operation issues between Regulatory Body and Other Authorities Involved in the Licensing Process (Czech Republic)

Human resources management with special focus on training and licensing (Republic of Korea)

Commissioning and project management (China)

Application of TC Regional Asia Reference Book in cascade training with special focus on maintenance (Republic of Korea)

Plant specific safety indicators for monitoring operational safety performance (China, India, Pakistan)

Self assessments and peer reviews (China)

Methods to detect, correct and prevent human errors (India)

Education and training for safety (Republic of Korea)

Ageing and plant life extension (Republic of Korea)

Simulator training course (Republic of Korea)

Mechanical equipment course (Republic of Korea)

Steam generator course (Republic of Korea)

HIGHLIGHTS OF SESSION A
HOW TO INCORPORATE NEW SAFETY CAPABILITIES THROUGH EDUCATION AND TRAINING

Z. Szatmáry
Director, Institute of Nuclear Techniques
Budapest Technical University, Hungary
H-1521 Budapest
szatmary@reak.bme.hu

The interest of the young generation for nuclear subjects is definitely less than it was decades ago. This tendency corresponds to the general situation of nuclear power all over the world. However, there are differences between countries.

Symptoms of this general tendency are: decreasing number of students, problems of funding, many universities closing courses in the nuclear field, etc. These are especially apparent in those countries which developed large nuclear programmes in the past (e.g. UK, USA) but where no new power plants are on order. The situation is different in countries where smaller scale nuclear programmes are going on (e.g. Slovenia): a roughly constant or slightly increasing number of students learn nuclear technology. Typical figures are: 5 to 10 students per year which is normal for a small country (like Slovenia or other countries in Central Europe) but is considered as small for larger ones (like the UK).

Many efforts have been made to manage this situation such as partnership with the industry (UK), integration of universities into a network for assuring excellence in all fields (Belgium), organising large scale festivals for attracting young students (Mexico), etc.

International organisations like the IAEA play a significant role in maintaining competence in nuclear safety. They regularly organise schools, training courses both for professionals and newcomers (operators, researchers, regulators, etc.). It is done on a systematic basis in order to cover all fields of interest. Other activities like preparation of SAT (Systematic Approach to Training) documents, safety guides, etc. as well as OSART and ASSET missions have the same objectives.

The eventual loss of competence will have negative effects not only within the country where this happens. Most countries using nuclear technologies have imported them from those few countries which developed them (USA, Canada, France, Germany, Sweden, Russia). In this sense, the former group of countries depend on the vendors. If the latter lose competence in nuclear safety matters, this can have negative effects in the countries which imported their technologies.

SESSION B

How to Maintain and Continuously Develop Existing Safety Capabilities

Chairman: J. Furness

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
Exhibition Road, London SW7 2BX, UK.
a.goddard@ic.ac.uk

Abstract

My purpose in 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. I 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. Various performance measures, applied by the UK government, relate to contacts with industry 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. But other measures; for example numbers of PhD students and the volume of research contracts from industry, provide an additional incentive (over and above the direct benefits from contracts) for universities to foster close industrial links.

Industry is required to operate safely and profitably – and pressures from shareholders/stakeholders, the 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 are 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 touched on.

2. University research role

The United Kingdom government influences national research policy, at the highest level, through at 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. The foresight programme 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 and that allocate basic funds to universities, for specific research projects and 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 Forsight 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 univeristy 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 national core funding.

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

I 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 university 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 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, while meeting the objectives set by government? 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 effect 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 a particular sector industry is only one of these objectives.

I have included three examples of how the transfer, to industry, of basic research is being achieved in my research group. Research is conducted into Numerical Methods in Engineering of an original, basic nature, but the applications 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 finite element meshing, 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 I have selected is taken from a recent international conference paper (the work was performed by a PhD student) and the diagram shows improvements in PWR core of optimisation achieved by using a technique called Tabu Search rather than a conventional Genetic Algorithm approach.

(b) Self-adaptive finite element 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 un-reliability 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. The mesh has been adapted (optimised) in relation to the curvature of the thermal neutron flux.

(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. These methods have been coupled to radiation transport methods. Because such methods, if they are properly benchmark, 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.

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

5. PhD research training

Because a national Research Council funds are limited, with a high degree of competition, industry funding of a PhD programmes is vital for UK universities. I 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 and will work wholly in the university; students who will spend substantial periods working with their sponsoring industry, and students who essentially are employees of the particular industry. In the latter case, there have 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 and should have the motivation to have their next career placement either 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 Frederic Joliot/Otto Hahn Summer Schools in 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. Their expertise of these university staff covers topics such as structural mechanics, software reliability, criticality issues and human factors. The papers that are discussed 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

I 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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CHALLENGE AND ENDEAVOR TO NUCLEAR SAFETY COMPETENCE IN KOREA: FOR NOW AND INTO THE 21ST CENTURY

Manwoong KIM, Jong-In LEE, and Yeon-Hee HAH
Korea Institute of Nuclear Safety,
Taejon, Korea
mwkim@kins.re.kr, jilee@kins.re.kr, yhhah@kins.re.kr

Jin-Hong KIM
Ministry of Science and Technology
Seoul, Korea
jhkim@mostws.most.go.kr

Abstract

Korea has maintained a consistent national policy to ensure stable energy supply by fostering nuclear power industries, under the circumstances that natural energy resources are insufficient in the country. Over the last two decades under a comprehensive nuclear power programme to construct nuclear power plants, Korea has developed a nuclear infrastructure of its own, which consists of regulatory and industrial structures, human resource management, educational and training programmes, etc.

To perform safety regulations for nuclear power plants effectively and efficiently, the Korean regulatory body has developed its regulatory infrastructures including regulatory systems, human and financial resources, and education and training programmes. Reinforcement of regulatory policies, redirection of regulatory resources, and improvement of staff capability have been undertaken to enhance the effectiveness and efficiency of regulatory activities.

Since the international cooperation has become more active, using the regulatory experience and capability gained in the construction and operation of nuclear power plants, Korea actively participated in various international joint research projects through bilateral or multilateral cooperation activities.

I. Introduction

During the past two decades, Korea has made remarkable achievements in the nuclear power area such as the completion of nuclear power plant design standardization and development of a Korean Next Generation Reactor (KNGR). These achievements could be realized not only by using experiences and knowledge gained through the construction and operation of many nuclear power plants, but also by establishing self-reliance in nuclear power technologies

However, the recent economic and financial crisis since the late 1998 has decreased the demand for energy, making it difficult to implement the nuclear power programmes. The reformation of the social and economic infrastructure was urgently needed to strengthen competition and improve productivity effectiveness. In this regard, the nuclear industry including regulatory organisations restructured the infrastructures and downsized human resources of their own between 1998 and 1999, with a view to improving their effectiveness to reflect social demand.

Nevertheless, the comprehensive promotion plan for nuclear energy is still progressing steadily through the effective and efficient using of limited human and financial resources in nuclear-related fields. The nuclear power installed capacity and power generation rate planned in the National Nuclear Development Programmme are shown in Table 1.

Table 1. **Nuclear Power Installed Capacity and Power Generation**

Year / Items	1995	2000	2005	2010	2015
Number of operating units	10	16	20	25	28
Generating capacity in Mwe (%)	8,620 (26.8)	13,720 (27.5)	17,720 (27.5)	23,430 (33.4)	27,650 (34.2)
Power generation in GWh (%)	62,790 (34.5)	100,315 (40.6)	123,091 (37.4)	186,000 (41.3)	199,041 (46.3)

Source: The Fourth Long-term Electricity Supply Plan (1998 - 2015), 1998
1) Kori Unit 1 (587 MWe) will be decommissioned in April 2008.
2) Wolsong Unit 1 (678.7 MWe) will be decommissioned in April 2013.

2. Nuclear power programme

2.1 Nuclear development programme

A. Commercial nuclear reactors

Since the first commercial operation of a nuclear power plant, Kori unit 1, in 1978, the nuclear power programmes have steadily been expanding, and nuclear energy has now become the main source of electric power. At present, a total of 15 nuclear power plants, 12 PWR units and 3 CANDU units, are in commercial operation and 1 PWR in commissioning stage, generating about 42% of the total electricity produced in 1998. Besides, a total of four nuclear power plants are under construction and eight nuclear power plants are now planned for operation by the year 2015 and the increase rate of nuclear application is shown in Figure 1.

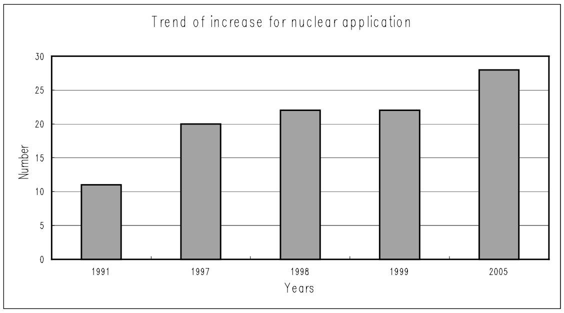


Figure 1. **An Increase Rate of Nuclear Power Plants**

B. Research reactors

There are three research reactors, namely TRIGA-MARK II, TRIGA-MARK III and KMRR (Korea Multi-purpose Research Reactor), and one critical assembly as shown in Table 2. The two TRIGAs have operated for the purpose of basic research and production of radioisotopes since the 1960s. However, they have been shut down due to their end of reactor lifetime and are presently in the decommissioning process. The KMRR, named HANARO (High-flux Advanced Neutron Application Reactor), was designed for 30 MW of thermal power. It first achieved criticality on February 1995 and is now operating at 24 MWth. Also, one critical assembly has been used for education and experiments in reactor physics.

Table 2**. Status of Research Reactors**

Reactor	Initial Criticality	Rated Power	Status
TRIGA MARK-II	1962. 3	250 kW	Shutdown
TRIGA MARK-III	1972. 5	2 MW	Shutdown
AGN Model-201	1982.11	Critical Assembly	In operation
HANARO	1995. 2	30 MW	In operation

C. Nuclear fuel cycle plants

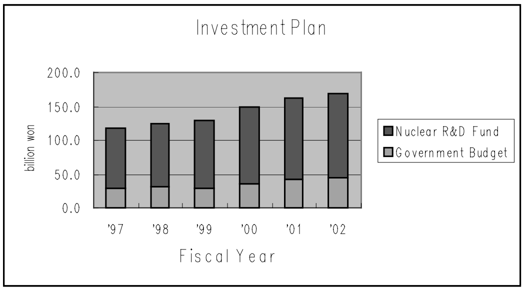
At present, there are two nuclear fuel cycle plants in operation. The first nuclear fuel cycle plant for CANDU fuel has been producing fuels with an annual production capacity of 100 MTU since 1987 and for PWR fuel operation with an annual production capacity of 200 MTU has been going on since 1989. Recently, a new fuel fabrication plant has been constructed with a capacity of 400 MTU for PHWR and 200 MTU for PWR, respectively as shown in Table 3. With the construction of this new fuel fabrication facility, Korea will have the self-supply capability required for nuclear power plants.

Table 3. **Status of Nuclear Fuel Fabrication Plants**

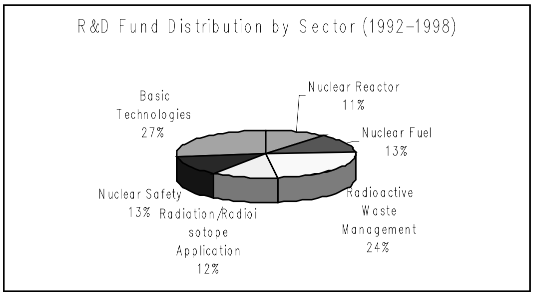
Facility	Fuel Type	Capacity	Utility
Nuclear Fuel Cycle Plant Unit 1	PHWR PWR	100 MTU/year 200 MTU/year	KAERI KNFC
Nuclear Fuel Cycle Plant Unit 2	PHWR PWR	400 MTU/year 200 MTU/year	KNFC KNFC

D. Nuclear research and design programmes

As for the nuclear R&D programme, a total of 6,555.5 billion won (approximately 5,300 million USD) is planned to be invested for the Nuclear R&D Programmes up to 2010. A total of 4,245.5 billion won (approximately 3,440 million USD) is to be supplied from the nuclear R&D fund and governmental contributions. The R&D fund was established by law with collection of 1,200 won per GWh (approximately 1 USD) based on the nuclear power generation record of the previous year. In 1997, this fund reached about one hundred million dollars. The seven main R&D fields, which are divided into 32 detail areas, are as follows; reactor, nuclear safety, nuclear fuel, radioactive waste management, application of radiation and radioisotopes, radiation protection, nuclear basic technology, etc. as shown in Figure 2.



(a) Investment Plan for Nuclear R&D Programme



(b) Nuclear R&D Fund Distribution

Figure 2 **Nuclear Research and Design Fund**

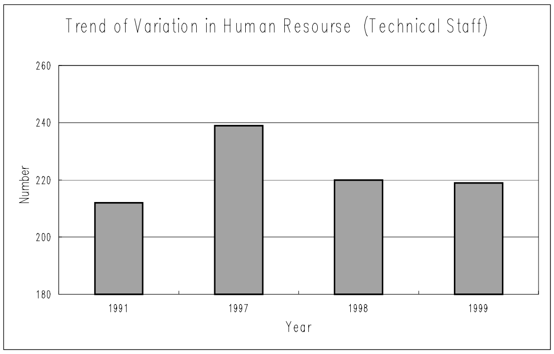
2.2 Human and financial resources

A. Regulatory organisations

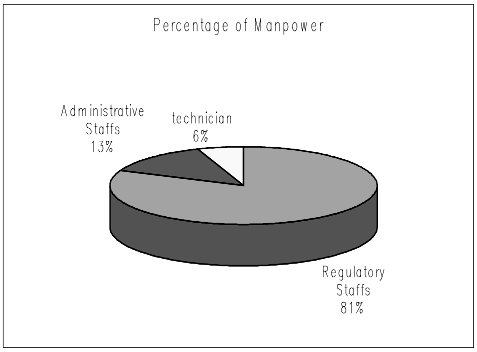
As aforementioned, the social and economic infrastructure reform has taken place in all industries including the nuclear field due to the recent economic and financial crisis in order to strengthen competitiveness and improve productivity effectiveness since the late 1998. Regulatory organisations have also carried out infrastructures restructuring and human resources downsizing on their own initiative.

The Korea Institute of Nuclear Safety (KINS), as an independent regulatory expert organisation, was established with a total of 331 staffs in 1990. Ever since, the number of staffs have stabilized and counted a total of 316 staffs as of October 1998 to meet the increasing regulatory demands caused by rapid expansion of the nuclear industry as shown in Figure 3. However, after recent infrastructure reforms the number of staff was decreased to a total of 269 staffs.

The average age of the technical staff is approximately 40 years and their average regulatory experience is about 11 years. And KINS staffs have a high level of academic qualification; 70 PhDs, 121 MScs, 63 BSs, etc.



(a) number of technical staff

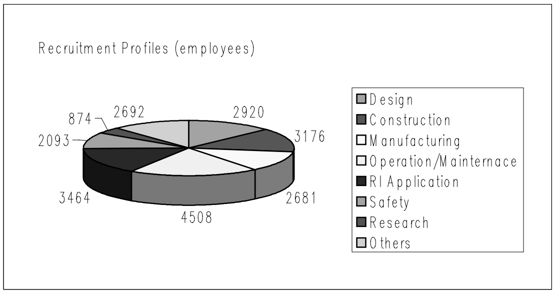


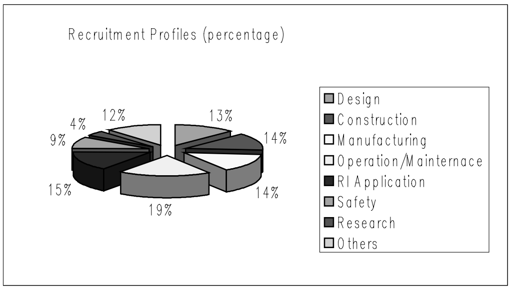
(b) distribution rate

Figure 3. **The Trend of Human Resources**

B. Nuclear industries

There were a total number of 23,006 employees working in the various fields of nuclear industry including regulatory bodies and research institutes as of 1997 as shown in Figure 4.





(a) number of employee (b) percentage

Figure 4. **Recruitment Profile in Nuclear Industry**

Regarding recruitment in the future, a survey of 96 nuclear industry companies, organisations and agencies including research institutes resulted in the following recruitment profile demand for the next 5 years as shown in Figure 5. It shows that recruitment in the design field will be an important consideration in the near future as the nuclear industry steadily expands.

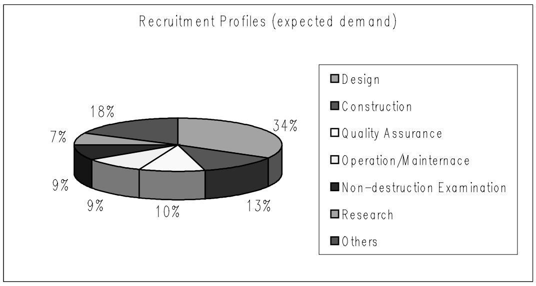


Figure 5**. Recruitment Profile Demand in Nuclear Industry**

Since Korea has no oil or natural gas reserves, and thus, must rely on imports for energy resource, there is no viable option but nuclear energy. Therefore, a total of 28 nuclear power plants are now planned for operation by the year 2015 and their total installed capacity will amount to 27.7 GWe For this reason, am increase of employees is expected in nuclear industries including regulatory bodies until 2015.

3. Education and training programmes

3.1 Regulatory organisations

A comprehensive and systematic education and training programme is vitally important for regulatory staff to develop and retain high level regulatory capability and competence in their profession. KINS has made an effort to effectively and efficiently perform its regulatory activities in order to achieve its regulatory goals aimed at ensuring the safety of nuclear facilities. To accomplish its objective, KINS established the Master Plan of Education and Training in September 1997. The objective of the plan is to educate and train its staff as well as to develop detailed training programmes. The educational programme consists of three levels such as a course for a new employee, for both junior and for senior staffs.

Besides these, assignment to the Resident Inspectors Office at a nuclear power plant site for a 2-year period, simulator training at KEPCO's Training Center, and overseas OJT assignments through the IAEA fellowship programme and KINS' own training programme for a 6-month to 1-year period are also offered.

In addition, KINS also has been encouraging its staff to enroll at a university or other academic institutes like the Korea Advanced Institute of Science and Technology (KAIST) to get advanced degrees. Since many staffs have taken this opportunity, this advanced degree programme has been playing a very important role in developing the technical capabilities of KINS staffs.

3.2 Nuclear industry

The Atomic Energy Act stipulates that the operator of a nuclear installation shall provide employees with educational and training opportunities. Accordingly, the Korea Electric Power Cooperation (KEPCO), a unique utility, provides employees with professional experiences by annually improving the educational programme. The educational programme consists of two categories; basic training and development training.

In 1977, KEPCO established the Kori Nuclear Education Institute for the purpose of developing technical manpower. This education institute is fully equipped with a simulator and various mock-up equipment including steam generator, fuel-reloading facility, and reactor coolant pump to enhance the maintenance capability of the personnel. At each nuclear installation site, the training center (Yonggwang, Wolsong, and Ulchin) is equipped with a simulator.

In accordance with the Atomic Energy Act, the license holder, the total number of 961 as of December 1997 by KEPCO, must participate in retraining programme. Besides, the KEPCO itself conducts a refresher programme twice a year for reactor operators. The major contents of the programme consist of nuclear safety culture, simulator exercises, technical specifications, and case studies of incidents and accidents.

4. International co-operation in nuclear safety

At the beginning stage of the nuclear power programme, the Korean regulatory body learned about regulatory infrastructure and technique from the vendor countries to assure the safety of nuclear power plants and partially adopted them into the Korean regulatory system. At that time, therefore, the major objectives of international cooperation were the development of technical capabilities of the Korean regulatory body by on-the-job-training at the vendor country's regulatory organisations directly or through the IAEA's fellowship programmes and also by inviting regulatory experts from vendor countries.

Entering the 1990s, international cooperation became more active drawing from the regulatory experience and capability gained through the construction and operation of about ten (10) nuclear power plants. In this era, Korea started to participate in various international joint research projects through bilateral or multilateral cooperation activities.

These days, KINS has cooperated with regulatory organisations of other countries such as the Nuclear Regulatory Commission (NRC) of the U.S.A., Atomic Energy Control Board (AECB) of Canada, Nuclear Safety Installation Directorate (DSIN) of France, National Nuclear Safety Administration (NNSA) of China, etc. Moreover, KINS has cooperated with nuclear and radiation safety related organisations such as Japan Chemical Analysis Center (JCAC) of Japan, China Institute for Radiation Protection (CIRP) of China, etc. Based on technologies and experience accumulated during the past two decades, KINS has expanded its contribution to improve the safety level of nuclear installations in developing countries through bilateral and multilateral cooperation since the middle 1990s as shown in Table 4.

KINS has also cooperated with the International Atomic Energy Agency (IAEA) in order to exchange technical information about regulatory policies and practices of member countries. The IAEA has supported KINS in various fields of safety review through the IAEA Technical Cooperation (TC) Programme and the Safety Service Programme. In the IAEA Advisory Commission for Safety Standards (ACSS) and its sub-committees namely NUSSAC, WASSAC, and RASSAC, many KINS staffs have participated. Also, KINS has also participated in the activities of the IAEA as shown in Table 5.

Due to Korea's affiliation with the OECD/NEA (Nuclear Energy Agency) since May 1993, KINS has participated in several NEA committees and programmes, such as the CNRA (Committee on Nuclear Regulatory Activities), CSNI (Committee on Safety of Nuclear Installations), the RASPLAV project, etc. With time, KINS' participation will be expanded to various working group meetings and joint research projects.

Table 4. **International co-operative research programmes**

Title of Project	Participant	Main Activity
IPIRG-2 (International Piping Integrity Research Group Programme)	15 Countries (Organized by USNRC)	To develop and validate methodologies for predicting fracture behavior of cracked piping for NPPs
CAMP (Code Analysis and Maintenance Programme)	20 Countries (Organized by USNRC)	Improvement of Computer Codes (RELAP5/MOD3 and TRAC-PF1/MOD2) for Safety Analysis of NPPs
CSARP (Cooperative Severe Accident Research Programme)	13 Countries (Organized by USNRC)	- Development of Computer Code for Severe Accident Analysis - Experimental Study of Severe Accident
MCAP (MELCOR Cooperative Assessment Programme)	15 Countries (Organized by USNRC)	Assessment of MELCOR Computer Code
SR5CAP (SCADP/RELAP5 Code Assessment Programme)	14 Countries (Organized by USNRC)	Assessment of SCDAP/RELAP5 Computer Code
RASPLAV	15 Countries (Organized by OECD/NEA)	Experimental Study of Reactor Cooling for Severe Accident Analysis
ISP-38 (International Standard Problem)	18 Countries (Organized by OECD/NEA)	Development and validation of computer code for safety analysis of low power operation
CRP (Coordination Research Programme)	12 Countries (Organized by IAEA)	Development of Risk Information Approach Using PSA Methodology
KJPSA (Korea-Japan PSA)	Nuclear Institute-Industry-University in Korea and Japan	Exchange of Technical Information on PSA
COOPRA (Cooperative Research Programme on Probabilistic Risk Assessment)	10 Countries (Organized by USNRC)	Exchange of Technical Information on PSA and in-kind contribution
Hualien LSST (Large Scale Seismic Test Programme in Hualien, Taiwan)	5 Countries (Organized by USNRC)	- To obtain earthquake-induced SSI (Soil-Structure Interaction) data at the site having the soil condition of prototypical nuclear power plants - To verify methodologies and computer programmes for soil-structure interaction analysis

Table 5. **Participation in international organisation's activities**

Organisation	Name of Activity	Country	Technical Activity	Duration
IAEA	OSART	German Federal Republic (Krummel NPP)	Technical Support in the Field of Technical Specifications	Feb. 16, 1987 – March 6, 1987
	Design Review Mission	Pakistan (Chashma NPP)	Design Review Mission	Sep. 5, 1993 – Sep. 19, 1993

5. Conclusion

To perform safety regulations for nuclear power plants effectively and efficiently, the Korean regulatory body has developed its regulatory infrastructures including regulatory systems and requirements with the adoption of regulatory provisions and practices of the supplying countries and those recommended by the international organisations like the IAEA. Although this approach has been working very well so far, the nuclear industry worldwide is facing a lot of rapid changes and challenges and Korea is no exception.

Under the circumstances, we have to reinforce our regulatory policies and priorities, to redirect regulatory resources to provide more effectiveness and efficiency in regulation, and also to improve the capability of regulatory staff. To enhance the effectiveness and efficiency of regulatory activity and safety, the education and training programme must be strengthened.

In order to maximize regulatory resources, the development of a database for all licensing related documents reviewed and inspection data accumulated up to date is required. As information and knowledge based regulation gets emphasized worldwide, the sharing of regulatory experiences, and the application them to the regulation of nuclear installations, KINS is preparing the safety review and inspection procedures which will be uniformly applied to all nuclear installations.

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WAYS TO MAINTAIN NUCLEAR SAFETY COMPETENCE IN FINLAND

Timo Vanttola and Lasse Mattila
VTT Energy
Nuclear Energy
P.O.B. 1604, FIN-02044 VTT, Finland
Timo.Vanttola@vtt.fi, Lasse.Mattila@vtt.fi

Lasse Reiman
Radiation and Nuclear Safety Authority STUK
P.O.B. 14, FIN-00881 Helsinki, Finland
Lasse.Reiman@stuk.fi

Abstract

In mid-1990´s, both Finnish nuclear power operators started extensive plant modernisation. National surveys indicated that the present age distribution of nuclear power experts implies shortage of resources through retirement within 10 years, unless education is timely enhanced. The current rate of nuclear energy specific education, about 10 master's degrees per year, will be too low, particularly if construction of new nuclear capacity were started. The problem is recognised, and some measures have been initiated. In Finland continued public funding for nuclear energy research is judged important to assure impartial expertise for the safety authorities. This research has been organised as national research programmes, where the requirement to raise experts is emphasised.

Challenging tasks have proved to be important in motivating the students and the permanent personnel. The specific features of the VVER reactors, participation in international R&D projects and, recently, design and assessment of ALWR concepts have offered such possibilities.

The image of nuclear energy affects the interest of young generation when choosing a career. One way to improve the situation is to increase communication with the public and direct information to the potential students. The need for other than technical skills is also reflected in the latest work programme of the Young Generation Network, organised by the Finnish Nuclear Society.

1. Introduction

Finland produces nearly 30% of its electricity with nuclear power. Consumption of electricity has increased at a rate of 2-3%/year and no decline is expected in the near future. At the same time public debate about the future production options and about the methods to restrict environmental pollution according to the international agreements continues. Contrary to the discussion in some other nuclear power countries, no moratorium has been seriously proposed, and even an option to build new nuclear capacity is requested by the industry and by some trade unions, and the possibility is also included in the political agenda of the present government. At the same time, deregulation of electricity market favours only short term decision making. In the ambiguous situation the national energy policy has been a very difficult issue and no clear resolutions on the top level have been made yet.

Site selection for the final disposal of spent nuclear fuel is the next big decision to be taken by the government in the year 2000, after which an application for decision in principle to construct a new nuclear power unit is expected from the industry. The decision about new capacity has to be given by the government and must pass the Parliament treatment. A similar application has twice been rejected, once in the aftermath of the Chernobyl accident in 1986 and previous time in the Parliament vote in 1993, which then led to alternative modernisation projects of the current NPP:s in 1996. At the same time operating licences of the plants were renewed for the next 10 to 20 years.

At present the Finnish NPPs are about in the middle of their estimated life span, and the continued operation of the units calls for attention on specific issues such as real remaining life of the plant components and structures and modernisation of I&C technology.

As a result of the early construction phase of the NPP:s in the seventies and the subsequent stable period of operation with plant renewals and safety evaluations, the age profile of the personnel among the plant operators, the safety authority and the research sector in the support organisations has evolved into a form with a peak in the range of 45 to 55 years. The current education and recruitment rate of personnel, particularly for highly specialised university level duties, has until now been enough to meet the immediate needs. Within ten years or so, however, shortage of human resources are expected to appear as a result of retirement, and even faster, if the new plant project were commenced. On the other hand, if the new plant project were cancelled, the future prospects in the nuclear safety field as a professional career would certainly weaken in the eyes of the younger generation. This would decrease students’ interest in the field and would later limit recruitment possibilities. At present in Finland competition about young technically talented people is very strong, with particular attraction from the telecommunication sector.

2. Needs

The recent modernisation programme of the plants also addressed ageing of personnel. The national surveys indicated that the age profile among the different actors of the nuclear safety field is strikingly similar, with a retirement boom starting in the next decade. Figure 1. demonstrates the situation with the Department of Nuclear Reactor Regulation at the Radiation and Nuclear Safety Authority STUK (Reiman, 1998).

In Finland the two nuclear power operators, Fortum and TVO, the regulatory body STUK, the technical support organisations (mainly VTT), institutions of higher education and the government continuously have to recruit certain amount of knowledgeable persons in the field of nuclear engineering. Depending on realisation of the future scenarios, certain enhancement of basic level education is needed.

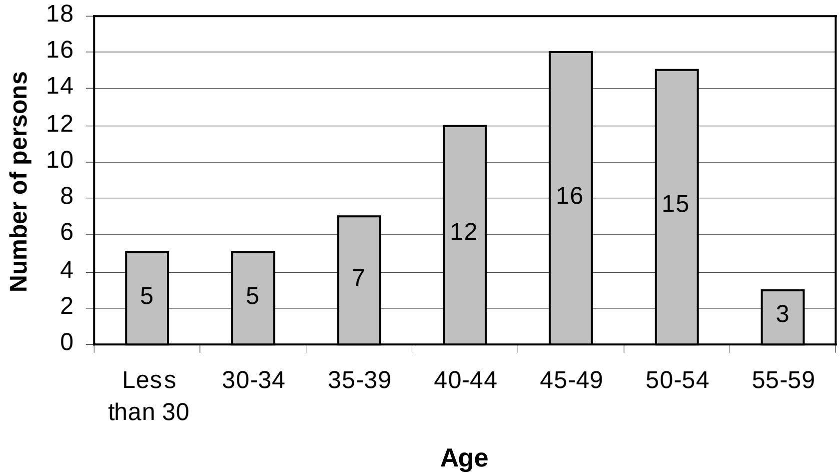

Figure 1. **Age distribution among the personnel at the Department of Nuclear Reactor Regulation of the Radiation and Nuclear Safety Authority STUK in 1998**

The base work load in the safety field comes from such tasks as continuous upgrading of the power plants and their way of operation with possible safety implications, periodical renewals of operating licences, adjusting safety regulations, making and evaluating safety analyses, developing of safety analysis methods and researching unresolved issues. Another nuclear safety related field is the back end of fuel cycle, which in Finland mainly concerns issues related to final disposal of spent fuel in the bedrock.

The need of education depends on the field of expertise. For purely nuclear energy related tasks, that have little or no application beyond nuclear power sector and with long specialisation period, immediate actions are needed. Such special fields are particularly reactor physics and some aspects of reactor technology related process engineering. Special education is also needed in the fields of control and instrumentation, material and structural engineering and water chemistry.

Further familiarisation of the new generation to the special fields mainly takes place in the power companies, the regulator and the technical support organisations. In this phase, it is important to reserve enough time for training and transfer of duties. Long enough on the job training also facilitates development of “collective memory” of the organisations beyond documented procedures, that is unwritten rules, reasons for strategy selections etc.

National surveys have indicated that in the training of high level experts it is often important to pay attention to wide enough approach already in the early phase of education, in the sense that understanding of systems behaviour is as important as deep understanding of details. In a small country like Finland, people with broad view and interdisciplinary skills are appreciated also because they add flexibility to our thin organisations.

Special international courses should be offered in fields that are beyond the resources of the domestic universities. Such courses are instructive also in the sense that they demonstrate the international character of nuclear safety work, and later on facilitate participation in international projects.

In addition to basic education and training of the young generation, it is important to maintain and develop professional skills of the more experienced personnel. It is a very demanding task to maintain work motivation, particularly if the future of the whole nuclear sector is unclear. There are various methods to tackle the question, such as encouragement to continuous learning, job rotation and e.g. new topics and participation to international projects in the research field. These methods should be applied systematically.

Considerable economical resources are continuously needed to maintain the obtained safety level. In the production sector, that is in the utilities, it is naturally easy to argue for investments that improve or maintain productivity, and also relatively easy to tolerate the needed additional safety measures. In the public sector, that controls and independently evaluates the safety, the needed level of funding might be in danger during the next years because of the requirements to cut the state budget, and particularly, if the current ban to construct new capacity continues. If this scenario came true, reorganisation of the public funding would be needed.

3. Education

In Finland basic higher education of nuclear technology is mainly given in the Helsinki and Lappeenranta universities of technology. They have concentrated on specific nuclear power expertise, in particular reactor physics, nuclear power plant processes and specific materials issues. In recent years some ten master-of-science examinations have been passed annually in these training programmes. This amount has been sufficient for the current needs, but during the forthcoming retirement boom the situation changes dramatically. The problem has been recognised in the nuclear community, and some measures have already been discussed.

In the basic education of other fields of technology related to nuclear engineering, no special measures are deemed necessary, except for offering some additional nuclear energy related courses, if the new NPP project were started. The potential need concerns such fields as material sciences, strength of materials, radio and water chemistry, mechanical engineering and instrumentation and control.

In tackling the education questions, good co-operation between the universities, the authorities, the utilities and the research organisations is needed. In Finland conversation between these bodies is continuous, e.g. in national advisory groups of the public organisations and in the steering groups of the public research programmes.

Of course, all organisations of the nuclear community help the universities in providing knowledgeable teachers for the nuclear courses and in providing challenging subjects for the final thesis works of the students. In these thesis works the students are able to concentrate on real problems with professional guidance. In recent years students in an earlier stage of studies have been addressed too by offering summer and part-time jobs. This has proved to be useful in the strong competition about mathematically skilled students.

Nevertheless, certain communication problems and lack of information, as concerns future career in nuclear safety field for present day students, frequently seems to appear. One reason for this is the blurred reputation of nuclear energy in publicity. As a result of the earlier backlashes of the industry when trying to pursue new nuclear capacity, the utilities have shown relatively low profile. It has proved useful to analyse the opinions and experiences of the students that have finally found their way to the training programmes. Such things as the quality of tutoring and offered computer tools have often come up. Job advertisements seem to reach the young generation best through internet. Anyway, more targeted information to potential future young employees is needed.

In Finland post graduate training in nuclear energy mainly takes place in research institutes and enterprises, that means normal on the job training in research and development projects, or as part of the regulatory work. National resources in the fields of specific training, such as advanced methods of reactor physics, are very limited. Such needs are most effectively met by sending the trainees to international special courses. The availability of such courses may, however, be limited in future, if the general antinuclear atmosphere prevails long.

Higher academic degrees have traditionally been obtained as a part of normal work by simultaneously participating in the theoretical courses of the universities, while the subject of the thesis may have been in close relation with the daily work. The positive side has been that the theses have often been practical with direct applications. The less positive side effect has been that the higher degrees have typically been reached in a late phase of the professional career. This problem has recently been addressed nationally by establishing specific graduate schools. Another way of speeding up the studies has been to apply grants from specific funds or research fellowships from the national Science Academy.

4. Research

Research has continuously been needed in the exploitation of nuclear energy for various reasons. In spite of all the possible measures taken, the specific risk of radiation leakage cannot be totally excluded. Therefore the changes in the power generating process and its environment that are intentional, evolve during time or occur suddenly through incidents, have to be analysed from safety point of view. At the same time the research also offers a splendid way of developing and maintaining nuclear expertise by offering new specific issues, but not allowing to forget the old ones.

In Finland some FIM 160 million (USD 27 million) are annually spent for various nuclear energy related R&D efforts, Fig. 2. The power companies fund directly more than half of the total volume and the public sector about one third. Half of the total volume is spent for nuclear waste management issues and nearly 40% for reactor safety, out of which about half is directed to fully or partly public research programmes FINNUS, ALWR and XVO. The largest of these programmes, FINNUS, concentrates on nuclear reactor safety related issues of the existing power plants with strong support from the safety authorities. ALWR deals with possible future solutions of nuclear power generation and XVO is directed towards plant specific ageing problems with particular support from the power companies. These programmes are mainly conducted at VTT.

In Finland public funding for nuclear energy research is judged important in order to assure national impartial expertise for the safety authorities. In launching the FINNUS programme (1999-2002), Fig. 3, particular requirement was set for each research project to raise new experts. Already during the first year the number of part time and summer time undergraduate trainees, added with recently graduated and recruited young researchers in the programme has been of the order of 20. It is expected that some 5 to 10 Master’s degrees and one to three Doctoral theses would be awarded annually in the programme projects.

In order to guarantee good motivation both for the undergraduate students and the permanent personnel of the nuclear safety field, it is important to offer challenging tasks. In Finland such problems of interest have typically been the many specific features of the VVER reactors (materials, reactor physics, thermal hydraulics), participation in major international R&D projects and, recently, participation in several international design and assessment projects of ALWR concepts.

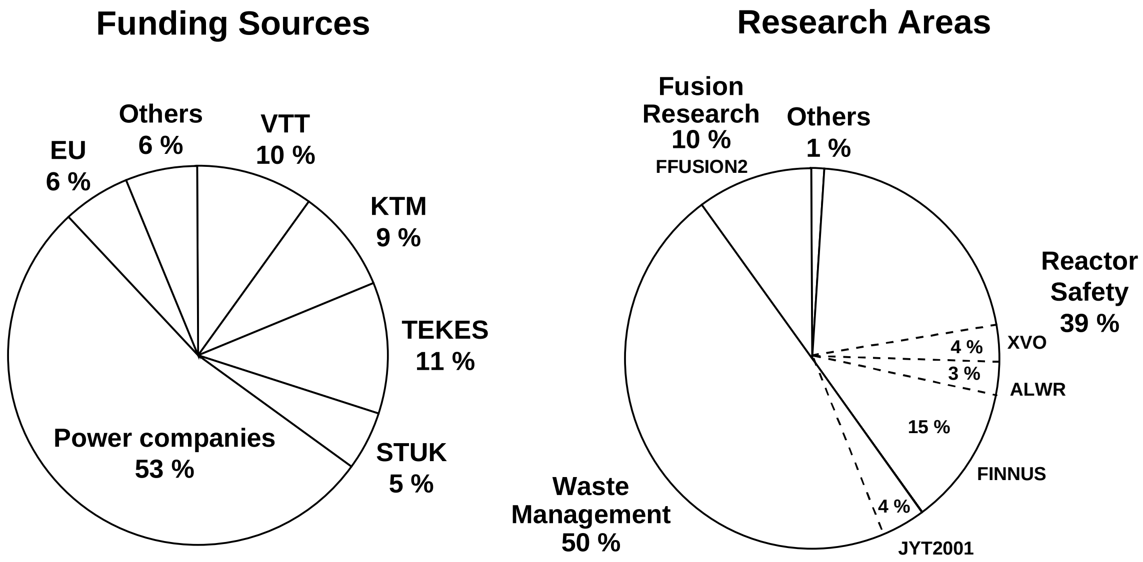

Figure 2. Resources of nuclear energy research in Finland in 1999. The public funding comes from the Ministry of Trade and Industry (KTM), the Technical Research Centre of Finland (VTT), the National Technology Agency (TEKES) and from the Radiation and Nuclear Safety Authority (STUK).

Although experiments are typically much more expensive than theoretical or computational work, it is very important to keep a proper balance with these methods. Traditionally emphasis has been on the thermal-hydraulic experiments with the PACTEL loop and material testing of metallic components in NPP conditions. In spite of the resource limitation, new types of in house experiments are planned, with problems related to interdisciplinary subjects such as thermal loading of wall materials as a result of flow stratification. In general, cooperation between the research fields of FINNUS is encouraged in order to broaden the scope of view and to prevent too strong splitting into narrow sectors.

In most of the research fields it is important to keep contacts with research of similar problems in the non nuclear field. This has led to products such as the thermal hydraulic APROS software with both nuclear and conventional applications in various types of power plant processes. As another example, the results obtained in the psychological research of operator training methods can be extended to many other fields.

It is important to keep the research groups vital so that the critical mass is reached, with proper age distribution and healthy turnover. This also means careful selection of research objectives, in order to provide exchangeable results for international cooperation, that is needed to overcome the national gaps. The national research programmes facilitate evaluation of such research needs.

In Finland a very important strategy decision was made already in the early phase of nuclear energy research, that is, most of the national research was placed inside VTT, that has always been a multidisciplinary research centre. Except for that it was a necessity for a small country with modest resources, it has enabled good contacts with all the fields of engineering and flexible exploitation of personnel and equipment resources.

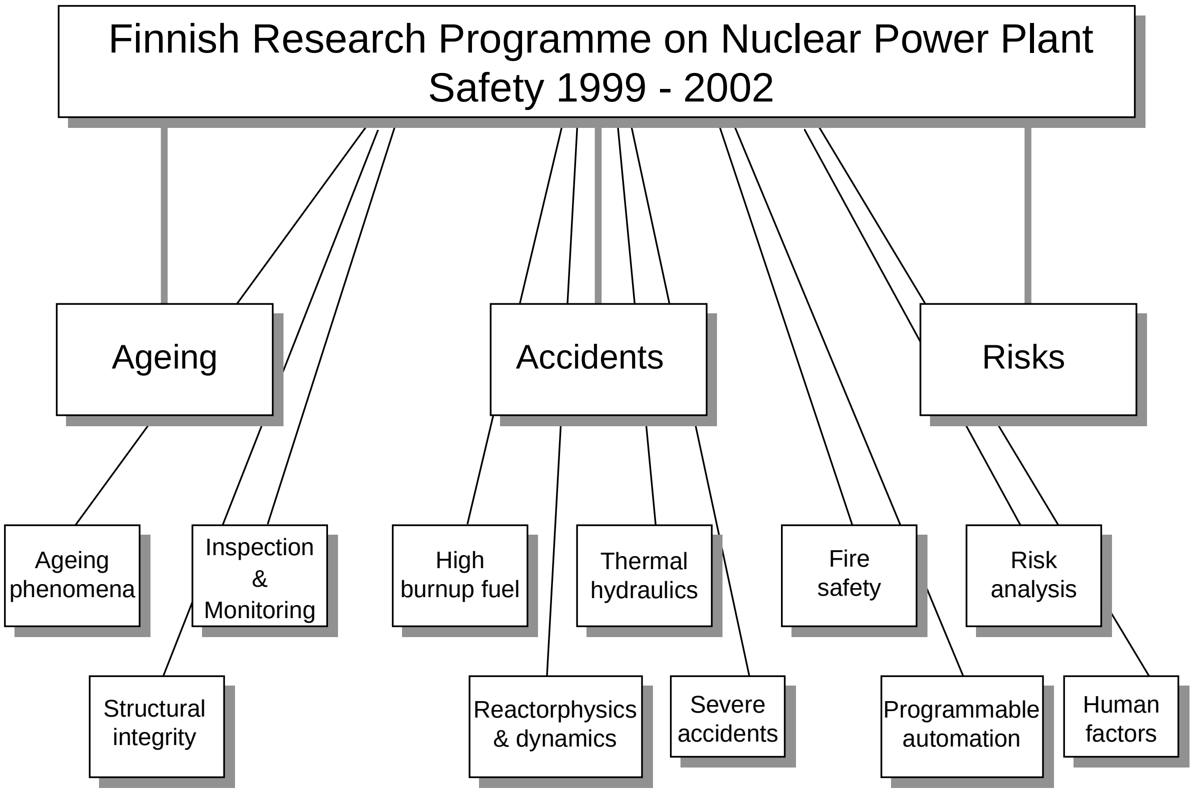

Figure 3**. Research fields of the FINNUS programme**

5. Other measures

The need to maintain nuclear safety competence is recognised within the regulatory body (Vuorinen, 1996) and power companies and various types of measures are planned and taken into use. The methods adopted by the power company TVO are separately presented in another paper of this meeting (Patrakka, 1999). Preparation for the gradual generation change has been started. Solutions are sought for maintaining work motivation and skills of the staff. Rotation of duties and adoption of the attitude of continuous learning are encouraged. The recent modernisation programmes and the evaluation of future concepts have also offered interesting tasks and a real opportunity to participate international cooperation both for the seniors and the younger generation. Most of these tasks have been conducted as part of normal work without any particular programme.

The image of nuclear energy strongly affects the interest of young generation when choosing a career. Making this field attractive is a very challenging task. One way of coping with the situation is to increase open and frank communication with the public, directly and via the media. The need for other than directly technical skills is also reflected in the latest work programme of the Young Generation network, mainly organised by the Finnish Nuclear Society.

6. Conclusions

The national survey of human resources in the context of the previous modernisation of the Finnish nuclear power plants indicated that the current amount of education in the nuclear safety field will turn out to be insufficient within 10 years. The shortage appears earlier, if the construction of new capacity were started. The question of sufficient basic education has been recognized in the nuclear community.

After basic education, the public research programmes have turned out to be efficient in the advanced training of new generation, and simultaneously they offer the chance to keep motivation and continuous development for more experienced staff. The research programmes also offer good possibility for national evaluation of priorities and a natural platform for international cooperation. The early Finnish solution to submerge major part of the nuclear energy research into polytechnic research environment has proved to be fruitful.

The safety authority and the power companies have adopted practical approaches in tackling the possible future resource problems. Such solutions as improved continuous training and familiarisation with future concepts have offered possibilities to maintain and improve working capacity.

In the long run, public acceptability of nuclear power is needed to guarantee continued high level resources for nuclear safety work. In this field mainly other than purely technical skills are needed.

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MAINTAINING STAFF COMPETENCE–
A NPP OPERATOR VIEWPOINT

Eero Patrakka
Development
Teollisuuden Voima Oy
27160 Olkiluoto
Finland
eero.patrakka@tvo.tvo.elisa.fi

Abstract

For a nuclear power plant operator, it is crucial to guarantee the safe and economic operation of the power plant as well as to look after the general acceptability of nuclear power. As to human resources management, this requires continuous maintenance and enhancement of the performance of the individuals and organisation. To this end, several development projects have recently been implemented by Teollisuuden Voima Oy (TVO) at the Olkiluoto nuclear power plant, which consists of twin 840 MWe BWR units that commenced their operation in 1978 and 1980.

Systematic initial and continuing training programmes are needed to maintain the technical and managerial skills and know-how at a high level. The present stabile state of nuclear power, i.e. operation of ageing plants with personnel ageing as well, requires a variety of actions to reinforce the training efforts. At Olkiluoto NPP, we have carried out an extensive modernisation programme that allowed the personnel to strengthen their knowledge and supplement it with the most recent results of development. We have also closely monitored the NPP development projects of the vendors, which has added to the preservation of know-how and understanding of advanced nuclear power technology. We have close contacts to the research institutes and universities, and have performed R&D activities to limited extent.

In addition to the projects mentioned above, a co-ordinated development programme, “TVO 2002”, was initiated last year. The main objective of this programme is to ensure the functional preconditions and the competitiveness of the company in a changing environment. The management and operational procedures will be developed in such a way that the goals set for year 2002 will be achieved. The programme is organised as ten projects, which cover a variety of development subjects. One of the focal areas includes projects that can be characterised with the words “Survey of competencies” and “Preservation of know-how”.

1. Challenges for operators to assure nuclear safety competence

For a nuclear power plant operator, the most demanding challenge is to maintain the safety. The total safety level is basically composed of three factors: machines, individuals, and organisations. All of them have a tendency to deteriorate if not actively taken care of. Machines wear, individuals loose their skills and organisations get stuffy. Regular actions are needed for keeping the performance as a whole above the risk level with a good margin.

1.1 Individual performance

A nuclear power plant is operated by individuals. People are fallible and even the best of them can make mistakes. Individuals at any organisational level should take responsibility for their behaviour and be committed to improving themselves as well as the task and the work environment. It is a challenge for the management to create a learning environment that encourages continuous improvement. Sufficient technical skills and know-how are natural prerequisites for excellence in human performance.

Not only skills and technical know-how, but job satisfaction is of importance when eliminating human errors. Special attention has to be paid to the work motivation as well as to the mental and physical conditions of individuals. Regular projects should be conducted in order to find out problem areas and to make necessary improvements. When a human error occurs, it should be analysed and exploited in order to prevent repetition of similar failures. Individuals at all levels should be encouraged to seek assistance and learn from mistakes. The management should focus on searching and eliminating organisational or work environmental weaknesses that have created the conditions for error.

1.2 Organisational aspects

Nuclear power plant operation presupposes strict discipline and follow-up of instructions to ensure safety in all situations. It means clear structuring of the operating organisation, allocating responsibilities and delegating authority within the operating organisation with a view to achieving proper management and minimising interface problems. All that must also be clearly documented and kept up-to-date. It is highly beneficial to have knowledge and creativeness of the whole organisation in an effective use. The challenge is to create an open working atmosphere where knowledge and creativeness of the whole personnel is exploited to the maximum extent without jeopardising discipline and order needed for assuring safety in all situations.

The effectiveness of the organisation is not necessarily dependent on the size of the organisation, as the competence is more important than the size of the staff. The operating organisation should include key experts which are able to exploit outside resources in an effective way. Well-functioning contacts to vendor and consulting companies, as well as to research institutes, have to be maintained all the time. A way to secure prompt access to technical support services is to have ready-negotiated frame contracts with those organisations.

2. Means to maintain and enhance staff competence

Sufficient technical skills and know-how are natural prerequisites for excellence in human performance. Systematic initial and continuing training programmes are needed to maintain those at a high level. In addition to that, the results of training shall be enhanced by combining training with other activities performed at the power plant.

A proven policy is to combine the development activities related to plant technology with the development of personnel competence. A plant, especially when performing well, may not by itself give technically teaching tasks for the staff. Challenging work by itself is the best trainee to encounter unexpected situations in a proper way. A good example of such projects is the modernisation of ageing plants which assists in maintaining and enhancing the technical know-how on plant design. This will be of benefit especially during a generation change in the professional staff, as modernisation tasks are very instructive for young engineers.

Job rotation is an indispensable element of human resources policy in a company and can be exploited as a tool in the design of individual training plans. The competence acquired in a position could be sufficient for another position without additional training.

Maintaining high competence presupposes in-house ability to perform transient and accident analyses to a certain extent. Also nuclear safety research and development of safety requirements should be closely monitored. Individuals should be encouraged to participate in international conferences related to nuclear power and to present papers there.

3. Design and construction projects

TVO's policy has been to keep a staff of a small size but of a high competence. The number of employees is about 480. The organisation includes key experts who are able to exploit outside resources in an effective way. Well-functioning contacts to vendors and consulting companies as well as to research institutes have been arranged. Our policy has also been to maintain open and proactive relations to the regulatory body.

3.1 Past projects

In TVO, a very important way to maintain and enhance the expertise of the staff has been the continuous carrying out of challenging projects. The most important projects since the plant commissioning have been:

- reactor uprating in the 1980s;
- severe accident mitigation;
- training simulator;
- PSA;
- interim storage for spent fuel;
- final repository for reactor waste;
- investigation programme for disposal of spent fuel;
- preparation of the specifications and evaluation of the bids for a new nuclear power plant.

3.2 Modernisation programme

The last mentioned project, stopped by the negative parliament vote in autumn 1993, was a natural starting point for a modernisation programme of Olkiluoto 1 and 2. All the drive and expertise focusing on a new plant were directed to the existing plant units.

The modernisation programme “MODE” was started in 1994. The time schedule of the programme was established so that the outcome could be utilised in the operation licence renewal in 1998. Modernisation tasks are very instructive and challenging for young engineers. Before being able to plan modifications, they have to be acquainted with the original design. This knowledge transfer is very important, because many of the key persons being involved in the plant design and construction will be retired in some years.

The main goals of the modernisation were as follows:

- reviewing safety features and enhancing safety, if feasible;
- improving the production-related performance;
- extending the plant life;
- maintaining and enhancing the expertise of the own staff.

In order to achieve the safety goal, the existing plant design was reviewed and compared to the present and foreseeable safety requirements. The need to fulfil new requirements was considered case by case. The living PSA model of the plant was utilised within this context.

Modernisation tasks would also be necessary for vendor companies which are suffering from the limited markets for new plants. There are less than 40 nuclear power plants under construction world-wide. In several countries, no new nuclear projects have been started since the 70s. This fact includes a risk that nuclear expertise, especially in design and construction related matters, will narrow down. Modernisation programmes will help vendors to maintain their ability to start new power plant projects if needed.

3.3 Present projects

An important contribution to the preservation of know-how and understanding of advanced nuclear power technology has been gained by monitoring the NPP development projects of the vendors. TVO is participating in the development of advanced BWR concepts by ABB Atom, General Electric and Siemens. Close contacts to the vendors are maintained also by virtue of various equipment and service purchases.

TVO is a full member in the European organisation developing the European Utility Requirements (EUR) document. The objective of this effort is to produce a joint utility requirement document aimed at the LWR nuclear power plants to be built in Europe beyond the turn of the next century. An interesting part of the EUR programme includes the development of specific EUR subsets for various reactor concepts.

We have close contacts to the research institutes and universities, and have performed R&D activities to limited extent. Finally, our memberships in several international organisations, such as WANO, VGB, ERFATOM and BWROG, must be mentioned.

4. Challenges for electricity producers due to changes in environment

The past years have brought numerous and significant changes in the environment where electricity producers are operating, and it is no difficult task to foresee continued changes in the future. For TVO, the most important impacts will originate from the following external issues:

- The electricity markets have been liberated and will become more and more international.
- Due to increased competition, the production costs are monitored even more closely than before.
- The societal control will intensify by means of taxation and emission limits.
- Changes in information technology will affect the operations, e.g. through networking.
- Euro has been implemented since the beginning of 1999.
- Common thinking and working patterns may change resulting in new conceptions for organisation models.

There are, of course, several internal matters that affect the circumstances. One example is the recent decision to construct the final disposal facility for Finnish spent fuel in Olkiluoto. Another important issue concerns the acquisition of competent personnel in the long term. If the present stagnation in the nuclear industry continues, it will be very difficult to attract young people into our field.

Such a multitude of challenges means that it is not possible to simply continue a straightforward operations model. Instead, one has to be prepared to face the changes by conducting proper development programmes. A successful implementation of the development programme will guarantee that the operational preconditions and competitiveness are maintained in the future. The key issue is to make the operations of the company more effective in all sectors.

5. Development programme “TVO 2002”

5.1 Objectives

In TVO we decided to carry out a development programme “TVO 2002” which has the objective to develop management and working methods in the company during the next few years in such a way the goals set for the programme will be attained by year 2002. The key words of this programme are “Quality-Management-Know-how”. During this programme a process will be generated during which the following tasks are performed:

- The challenges to be met in the future will be figured out.
- Strategies and development projects will be decided to encounter these challenges.
- Necessary changes in management and working methods will be determined.
- The agreed changes will be planned and implemented.

In addition to the main objective of guaranteeing the operational preconditions and competitiveness, another aim is to convince the personnel and interest groups of the fact that the company is performing actively and trustworthy, i.e. to strengthen a positive company image.

5.2 Basic assumptions

When planning a development programme one has to establish realistic starting point and boundary conditions. For us these include the following:

- TVO will concentrate in maintaining the production capabilities of Olkiluoto 1 and 2 and operating the plant.
- The company looks forward to start the construction of a new nuclear unit in the beginning of next decade.
- The company enters into marketing services related to its know-how along with its main activity.
- The personnel will be subject to a generation change during the next 10 to 15 years.

As there are inevitable uncertainties in the decisions made outside the company and having strong impact on our future, the programme must be built on alternative lines. More specifically, decision of an eventual new nuclear power plant project will be made in the beginning of 2001 earliest.

5.3 Implementation

Development programme “TVO 2002” is directed to the whole company. It consists of ten projects that are carried out in parallel. It is implemented in a process-oriented way which implies the application of different stages:

- initial decisions by the management related to the objectives and goals of the programme;
- process analysis including identification of key processes;
- planning of development projects;
- implementation of development plans.

Based on the initial studies, the following issues were selected for being addressed by the individual projects:

- process analysis;
- total quality system;
- human resources management;
- economical management;
- information technology;
- environment management;
- marketing of services and products;
- development of organisation and working methods based on the results of other projects.

6. Projects related to human resources management

Two projects in the development programme "TVO 2002" address specifically the development of human resources. The first one is called "Survey of competencies" and the other one "Preservation of know-how".

6.1 Survey of competencies

In the survey of competencies, first a methodology for the survey of know-how has been developed that covers the whole company. Then this methodology will be applied for all personnel to produce data for the planning of training programmes and personnel management. In addition to the own staff, subcontractor personnel will also be taken into account to the extent needed. The competencies map is divided into five sectors:

- basic knowledge and skills in working life;
- professional competencies;
- management and leadership;
- business operations;
- TVO-specific competencies.

The first sector covers all those basics that are required for almost all individuals working in a company. The professional competencies are further divided into several sub-sectors according to the disciplines in a nuclear power company. Management and leadership skills are obvious prerequisites for persons occupying supervisory positions. With business operations we mean basic knowledge and skills related to the economical way of thinking in a company. The last sector represents those competencies that are specific for TVO, e.g. safety culture and requirements set by regulatory body.

The survey of competencies takes place for all individuals in two stages. First, a map presenting the target level will be compiled where, in addition to the present situation, also the competencies that would be needed in future for the position in question are included. Second, the prevailing competencies levels are found out in co-operation with the individual and his superior. The outcome of this process will constitute of list of shortages and corrective actions. Such individual competence profiles will be used in the planning of training.

The survey requires substantial resources from the personnel. However, in this way we will have a good comprehension of the prevailing competencies levels and the corrective actions needed. Several tools exist for performing improvements: tailor-made training, project tasks, job rotation, secondments in other companies. We believe that this process will also intensify the use of training resources when resulting in much more need-oriented training.

The survey produces a multitude of data that must be stored in an easily accessible way. We are developing a specific information technology system that is able to assist the training staff, superiors and all individuals to design and follow-up the development of competencies. Importantly, this system will enable us also to control the competencies of subcontractor personnel and to make sure that all necessary knowledge and skills will be available at the own staff or subcontractors, when needed.

6.2 Preservation of know-how

A logical continuation to the survey of competencies will be to develop methodologies for personnel and information management that will assure the preservation of sufficient knowledge and skills for plant operation and project activities in the long term. This is the objective of project “Preservation of know-how”. Know-how here covers both individual know-how and structural know-how.

TVO’s personnel is in possession of substantial know-how that has been developed partly during the construction and commissioning of Olkiluoto 1 and 2 and partly on the basis of experiences gained in the plant operation and the projects carried out by the staff. This special know-how covers a wide range:

- management of NPP projects;
- design, construction and commissioning of NPPs;
- operation of NPPs combined with the particularities;
- knowledge of the technical features of Olkiluoto 1 and 2;
- knowledge of suppliers and subcontractors in Finland and abroad;
- management of regulatory issues;
- management of NPPs including safety culture.

A particular challenge for the project is to cope with the forthcoming generation shift. It must be observed that several of the special competencies are TVO-specific, i.e. their preservation is fully dependent on measures undertaken by TVO. For example, the development of university education in Finland very much depends on the actions and attitude of nuclear power plants.

The preservation of know-how consists of three sequential sub-projects:

- risk assessment of personnel changes;
- competence management system;
- learning organisation.

In the first sub-project, two tasks were performed. A detailed assessment was made on the medium and long-term needs to recruit new personnel based on the age profile of present personnel. The results will assist the managers to plan their personnel management activities. Further, a recommendation was made to facilitate job rotation. Many persons have hold their present positions for one or even two decades, and new duties would certainly give them more motivation for their daily work. New ideas would be brought to develop the working methods.

Competence management system is a combination of various activities. The results of competencies survey are closely monitored. The aim of this sub-project is to draw general conclusions on the basis of competence profiles and corrective actions produced in the survey and to make proper recommendations to the management. Another item in the sub-project is related to the results of a project in the information technology field where the information banks of the company where mapped out. It is essential to understand how these information banks are created and maintained and what is a proper way to retrieve information from the banks. Due to the huge quantity of data generated during the past years, this is no easy task, and deserves a lot of attention in the coming years.

The final outcome of the preservation of know-how should be a learning organisation. This will guarantee that the organisation has the ability to create, purchase and transfer know-how and, particularly, change its own behaviour on the basis of new knowledge and conceptions.

7. Conclusions

Since the initial recruitment and training of the personnel, continuing efforts have been devoted to maintain and enhance the competence of Olkiluoto NPP staff. Our systematic training programmes have been augmented by providing individuals with opportunities for challenging work in various plant development projects. These include an early reactor uprating project, various nuclear waste projects, preparation of the specification and evaluation of the bids for a new nuclear power plant, and a major modernisation programme of Olkiluoto 1 and 2.

Well-functioning contacts to vendors and consulting companies as well as to research institutes have been arranged. An important contribution to the preservation of know-how and understanding of advanced nuclear power technology has been gained by monitoring the NPP development projects of the vendors.

Numerous and significant changes in our environment have already taken place, and more of them will appear in the future. To meet the challenges brought by such changes, a co-ordinated development programme was initiated by TVO last year, addressing both the management and working methods in the company. One of the focal areas this programme includes projects that can be characterised with the words “Survey of competencies” and “Preservation of know-how”. We aim at a successful organisation that has the ability to create, purchase and transfer know-how and, particularly, change its own behaviour on the basis of new knowledge and conceptions.

ASSURING NUCLEAR SAFETY COMPETENCE INTO THE 21st CENTURY A SWEDISH PERSPECTIVE

Gustaf Löwenhielm and Gerd Svensson
Swedish Nuclear Power Inspectorate
SE-10658 STOCKHOLM
gustaf.lowenhielm@ski.se, gerd.svensson@ski.se

Ingemar Tirén
Safetech Engineering AB
Domkyrkoesplanaden 5
SE-721 13 VÄSTERÅS
(deceased)

Abstract

Many initiatives have been taken and are being considered to maintain and develop competence in the nuclear field in Sweden. The number of qualified nuclear engineering staff at the plants and at the regulatory bodies appears to be rather small for all important tasks to be carried out. Nevertheless, the current programmes indicate that one can look at future recruitment and competence with some confidence–in spite of the age profile of qualified staff with many approaching retirement.

The Swedish Nuclear Power Inspectorate, (SKI), the academic community, and the Industry are conducting several research projects that support the optimistic view expressed above. Examples include:

- **Safety research at SKI and universities:** Since many years, SKI is sponsoring research in safety analysis within the framework of its Research Programme. In this programme the regulator supports two professors, one in Nuclear Power Safety at KTH and the other in the Interaction of Man, Technology and Organisation at the University of Stockholm.
- **Swedish Centre of Nuclear Technology:** A main activity of the Centre is to support PhD candidates (with scientific advice and economy) in topics related to nuclear technology.

The Industry also makes great efforts to support recruitment by various initiatives:

- **Design reconstitution projects:** Each one of the older operating plants was subject to a design review that engaged a large number of young staff at the utilities and the vendors.
- **“Young Generation”:** It constitutes a communication network among young engineers at European nuclear plants, regulators, and other organisations.

- **ERFATOM:** This organisation is sponsored by the ABB Atom BWR Owners Group. Its main task is to analyse disturbances at the Nordic BWRs, and to recommend measures to prevent their recurrence.

There are several challenges ahead to preserve the competence in Sweden. The most important ones are 1) the deregulation of the electricity market and 2) the recent parliament decision to close Barsebäck 1 by November 30, 1999. At the same time the parliament decided to revoke the earlier decision to phase out nuclear power by the year 2010. In the current political situation, recruitment difficulties in the nuclear branch in Sweden may be foreseen. However, as nuclear power will remain beyond 2010 the competence must be maintained.

1. Introduction

In Sweden, twelve LWRs are being operated since the start in the 1970s. Nine of the plants are Boiling Water Reactors (BWRs) designed and manufactured by ABB Atom AB, the domestic vendor, and three units are Westinghouse PWRs. Continued and strengthened competence among those who operate, maintain and regulate them is considered to be a key element in preserving a high level of safety into the 21st century.

The Swedish Nuclear Power Inspectorate (SKI) has provided comments to the Committee on Nuclear Regulatory Activities (CNRA) on SKI views regarding recruitment and competence in the nuclear branch and the need to make changes in government policy in order to stimulate recruitment and boost competence. This paper is intended to give both the a) industry response to this development and to present some specific initiatives that have been taken by the industry to support recruitment and competence and b) the regulatory initiatives to recruit strategic technical competence and conduct associated regulatory research.

2. Recruitment situation and competence in the industry

2.1 Some comments related to the Convention on Nuclear Safety

In 1994 a thorough review of the situation in Sweden concerning recruitment and competence in the nuclear branch was made. A need was felt to ensure that sufficient resources in reactor safety would be available in the face of the strategic political decision to abandon nuclear power in Sweden. Official investigations were conducted regarding the situation in the State owned sector of NPPs (Vattenfall AB) as well as the private one (Sydkraft AB) (SOU 1990:40, 1990; Hörmander, 1994). The investigations identified the threats against recruitment and competence as a result of the political decision, and presented actions to take in order to mitigate its consequences. An account was given of the recruitment needs at the NPPS, on an extended time scale, and the availability of qualified persons for the jobs to be done. The latter aspect indicated the need to focus on the education, both at universities and at industry organisations, on more qualified engineers in specific topics.

Today, the situation has not changed much in these respects. Sweden responded to the IAEA Convention on Nuclear Safety (Ds 1998:54), explaining the Swedish implementation of the obligations of the convention. Several features have contributed to make the Swedish NPPs quite competitive internationally from a safety and environmental impact point of view. Room for improvement was, however, identified in some areas. On the industry side, SKI points out the following items:

- The older reactors in Sweden are not designed according to current safety standards. Modernisation programmes are being implemented following comprehensive design reconstitution projects that are described in Section 3.1 below. The newer units are also being assessed. The regulatory bodies, as well as the utilities, are working to define specific requirements to be applied to operating plants after the year 2000.
- The number of qualified nuclear engineering staff at the NPPs and the regulator seems to be rather small to suffice for all important tasks to be carried out. This is demonstrated by a shortage at the NPPs of human resources for comprehensive engagement in activities related to preventive safety. The increasing number of experienced staff that is now retiring, new regulatory requirements and all the new tasks to be done as a result of the extensive modernisation activities will even more emphasise the demand for qualified engineers and other specialists.
- Other regulatory initiatives, affecting primarily the regulators, are mentioned in Chapter 4 below.

Nuclear power in Europe – including Sweden – is becoming less competitive than it was, following deregulation of electricity. There is the view that this development brings about a declining availability of persons with key technical competence in the industry.

The basic prerequisites for responsibility for the safety at the nuclear power plants in Sweden follow from the law on nuclear activities. According to the law the nuclear power plant owners have the full and undivided responsibility for the necessary actions to uphold the safety at the plant. The responsibility of SKI is to specify more clearly the purport in the law and also watch over how the plant owners fulfil their responsibility. SKI must therefore have a well-founded picture of the safety situation and the quality of the safety work at the NPPs.

2.2 Interviews with personnel directors at the Swedish NPPs

Brief interviews with the personnel directors at the Swedish NPPs were made in order to get their views on recruitment and availability of technical competence in their staff in a five year perspective. These interviews are quite consistent and bring out the following points described below.

- For a long time, there has been uncertainty regarding the future of the Barsebäck with the political threat to have the plant shut down at an early date. The plant is also located in a region with remarkable industrial growth. In spite of these factors experience shows that the utility has managed recruitment problems in a satisfactory manner through the years.
- The interviews bring out clearly the fact that the decision to close Barsebäck 1 by November 30, 1999, does not spoil the long term planning of the utilities. Recruitment for the future is made irrespective of current political winds. A twenty years planning horizon is always maintained at the plants.
- Retirements due to age are predictable. At all plants there is a stable and loyal work force with a fairly low (around 5%/year) turnover of personnel.
- A problem to maintain an adequate number of highly qualified engineers in key technical areas is recognised, and the problem may be aggravated by reduced economic freedom due to the deregulation of electricity in Sweden. A closer co-operation with the

universities is quoted as a means to ensure that the required competence is made available and developed.

2.3 Long-term competence

To summarise, there are a number of threats to maintain the competence in the nuclear industry in the long-term. Deregulation was mentioned in the previous section and the government decision to close Barsebäck 1 by November 30, 1999, means that students are less interested to study these courses at universities. It also means that it is of less interest for universities to replace retiring professors in the same subject and there will be a shift to other subjects outside the nuclear area. At the same time the decision to revoke a phase-out by year 2010 means it is vital to upheld competence beyond 2010.

Below the reconstitution projects are noted as a mean to upheld the competence at both the vendor ABB Atom and the power utilities. These projects are less intensive today and will end within a year. ABB Atom has already adapted to this new situation and decreased the number of employees in the nuclear area.

3. Initiatives taken to stimulate recruitment and boost competence

Many initiatives have been taken and are being considered to maintain and develop competence in the nuclear field in Sweden. The current programmes indicate that one can look at future recruitment and competence with some confidence – in spite of the age profile of qualified staff with many approaching retirement. The following sections summarise some projects, which are considered important.

3.1 Design reconstitution projects

There is a continuous watch-out for any safety risk during the operation of the plants, and the older plants that have operated since the 1970s are particularly important in this respect. A comprehensive evaluation of the plant will provide assurance that any safety problem is detected. The clogging of emergency core cooling strainers that was discovered in 1992 and led to a stop of five Swedish BWRs emphasised the need for re-evaluation and triggered the initiation of the design reconstitution projects. These were carried out in close co-operation between the plant owners and ABB Atom AB, the plant vendor. They were initially applied to Ringhals 1 and the three “identical” plants, Oskarshamn 2 and Barsebäck 1 & 2, and were later extended to the more modern plants at Forsmark. The total investment was of the order of 400 man-years. The main motives for this substantial effort can be summarised as follows:

- Need to verify the safety level of the plant.
- Wish to investigate whether plant improvement (incl. retrofit) can increase safety or reliability.
- Need to improve description of and knowledge about the design base for the plant and its structural, mechanical and electrical systems.
- Need to transfer knowledge between generations and organisations.

In Figure 1 the elements of a design reconstitution project are illustrated.

Among important findings from the projects one may note – as examples – improved understanding of physical processes, particularly related to structural load combinations that were not properly accounted for, and transients affecting the primary system. Residual heat removal from the plant up to and including the ultimate heat sink, in combination with the appearance impurities in the cooling water canal, could also be a problem in some plants.

The accomplishments of the design reconstitution projects demonstrate that the approach is effective to:

- verify the safety level of the plant;
- provide a basis for plant modernisation;
- maintain and develop knowledge and experience related to the design of the plants. Competence is transferred to the younger generation of engineers at the plants and the main vendor. This is a major justification for the substantial expenditure in these projects. It is also an important factor in assuring nuclear safety competence into the 21st century in Sweden.

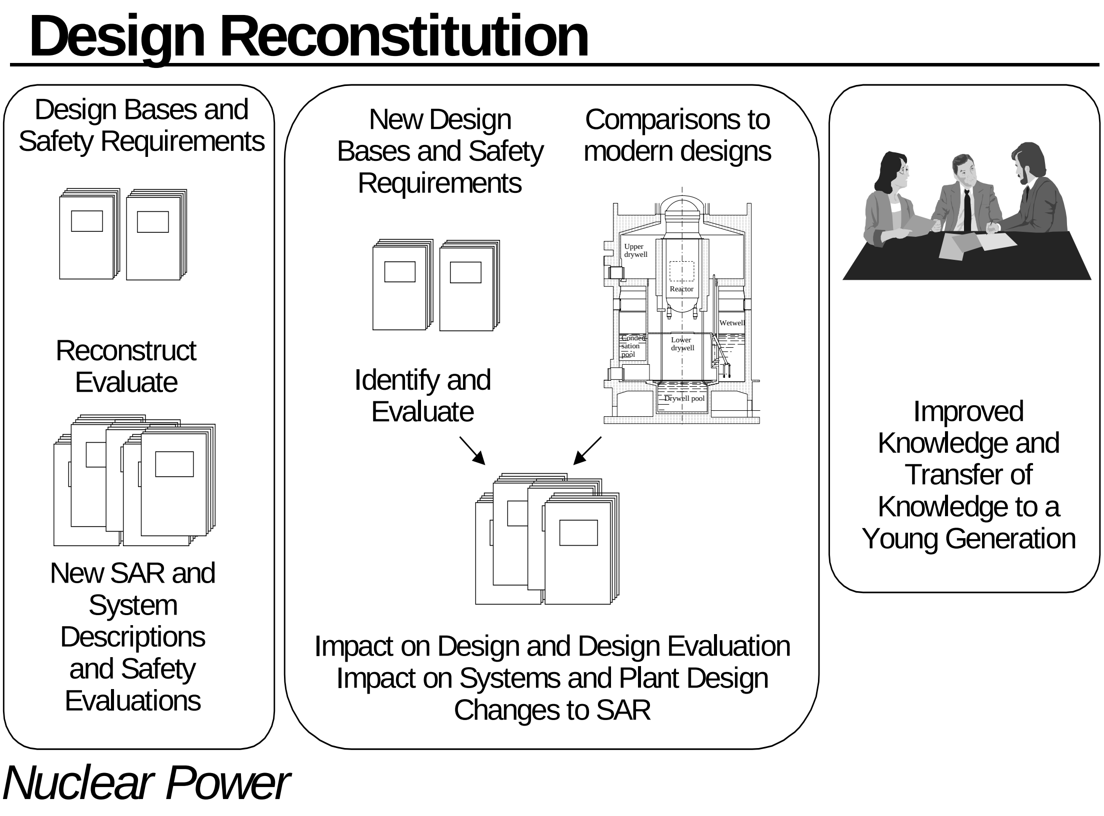

Figure 1. **Important elements in a design reconstitution project**

3.2 *“Young Generation”*

The initiative to “Young Generation” was taken by Jan Runermark, ABB Atom´s former President. He realised the need to transfer knowledge about the plants to younger generations of engineers and to demonstrate that engagement in the future of nuclear power is worth while. The need to take action was emphasised by the present retirement of those who built the plants (ENC, 1998).

All companies in the Swedish nuclear branch responded positively to the idea, and so in 1994 the first group of “Young Generation” engineers (YG1) was formed. It consisted of 120 participants from ABB Atom, the nuclear utilities, SKB, and the Nuclear Power Inspectorate. New groups have been formed annually since the start.

The purpose of “Young Generation” is:

- to focus on the next generation of engineers;
- to develop personal networks;
- to increase knowledge about nuclear power in a broad sense;
- to transfer knowledge between generations.

The activities include seminars, conferences and educational visits as well as in-depths studies of specific topics in smaller groups.

“Young Generation” has attracted great interest all over Europe. On the initiative of the European Nuclear Society (ENS) the “Young Generation Network” (YGN) was formed. There are now representatives from 15 European countries. There is no doubt that the YG organisation is an important factor in assuring nuclear safety competence into the 21st century.

3.3 *ERFATOM*

ERFATOM is sponsored by the ABB Atom BWR Owners Group. Its main task is to analyse disturbances at the Nordic BWRs, and to recommend measures to prevent their recurrence. Its activities began in 1994. A qualified group of engineers from the operating organisations of the plants and from the ABB Atom engineering division participate in this work. Every Licensee Event Report (LER), sent weekly from the operating plants to SKI, is scrutinised and processed. Findings are sent to the operating organisations at the plants for information and appropriate action.

Similar information from the two BWR plants in Finland, Olkiluoto I and II, is also obtained by ERFATOM on a regular basis and is processed and evaluated in the same manner.

Briefly, the main goals of ERFATOM are (Unneberg, 1995):

- to reduce the risk that events harmful to safety are repeated;
- to enable that knowledge and insight, based on experience or new findings, is being utilised;
- to ensure that essential design bases and design conditions are known and available to all concerned.

The continuous feedback of operating experience provided by ERFATOM strengthens significantly the safety competence in the industry for years to come. The working group gives the participants profound insight in the safety aspects of the operating plants, and participation is very attractive to the staff.

European Utility Requirements

In the early 1990s, seven European nuclear utilities began drafting of requirements for the design of new LWRs. The aim was to establish rules for standardised designs that could be approved as a basis for building new LWRs on a majority of European sites. The document is known as EUR – "European Utility Requirements" (EUR, 1995). In 1994, a first draft, Rev. A, was issued for comments from other utilities and vendors, see Figure 2. In 1995, Sweden and Finland became members of the European Union. Shortly thereafter the Swedish utility FKA (Forsmarks Kraftgrupp AB) and the Finnish utility TVO (Teollisuuden Voima OY) joined the effort of developing the EUR document.The EUR project includes the assessment of specific designs, i.e. an analysis of the compliance of these designs with the EUR requirements. Currently, the Franco-German EPR, the European Passive Plant (EPP), and the ABB Atom BWR 90 designs are the subjects of EUR assessment, based on the second draft of EUR, Rev. B.

In 1997, the two Nordic utilities mentioned above, joined by KEMA Nederland B.V. (now NRG), volunteered as "promoters" to carry out the assessment of BWR 90. It was decided that the

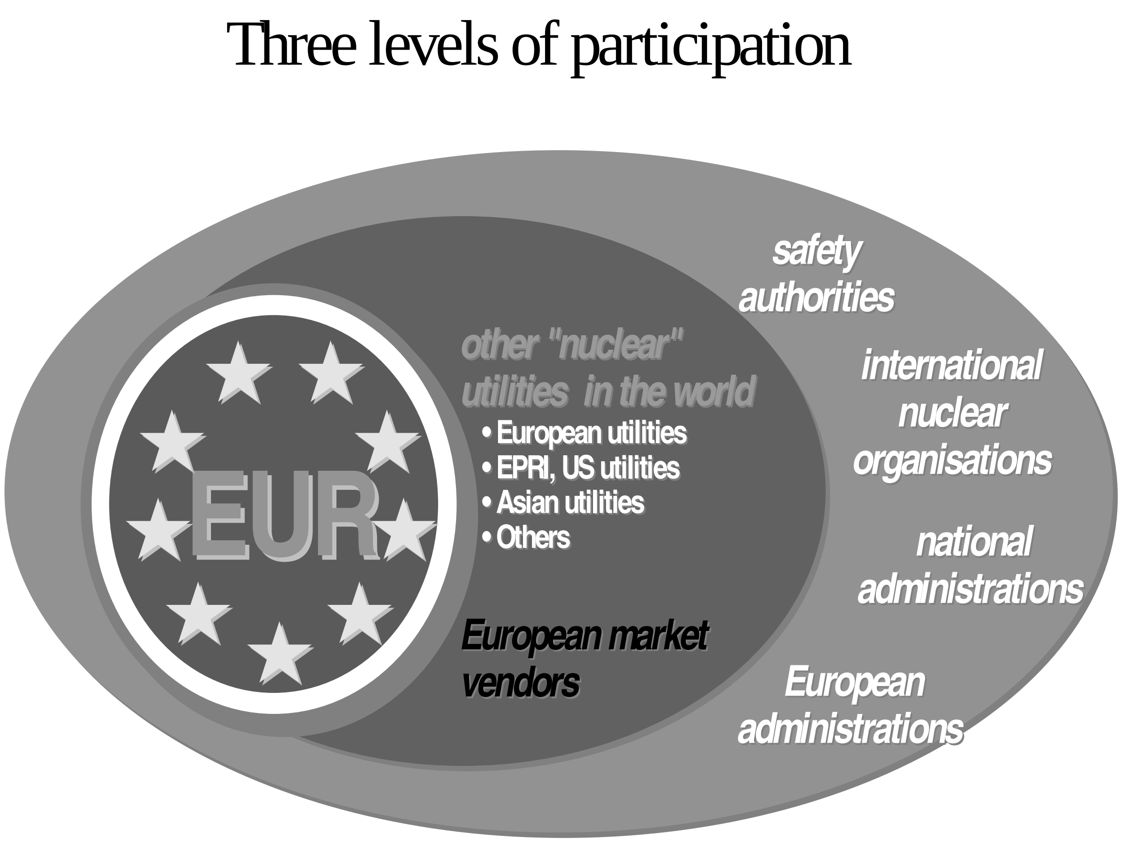

Fig. 2 EUR, co-operation with other organisations

plant as offered in 1991 for a fifth nuclear power plant in Finland, “Olkiluoto III”, was to serve as a basis for the assessment since this design is well described by bid documentation. The Olkiluoto deal was not closed since in 1993 the Parliament of Finland decided not to build another nuclear plant for the time being. Nevertheless, ABB Atom and utilities continue to co-operate in the development of the design under the acronym “BWR 90+”. For some severe accident issues both the BWR 90 and the BWR 90+ designs were assessed.

The assessment of BWR 90-Olkiluoto III represents an engineering effort among the EUR utilities and ABB Atom of the order of 10 man-years. It implies a thorough review of the design, including all essential characteristics of the plant, by several independent assessors. While the utilities issued no unconditional approval, their message is a clear “go ahead” to the BWR 90 (and BWR 90+) design.

The assessment can serve as a first step in a commercial process aiming at quotations for new LWRs in Europe. In the near-term, it will be useful in the efforts of the Nordic utilities to find suitable prototypes for upgrades and modernisation of operating plants in Sweden and Finland. The analysis will also be used by the vendor as an input to the further development of BWR 90+. In conclusion, the EUR / BWR 90 exercise will be useful in maintaining and developing knowledge about modern BWR technology.

The EUR project has also asked for comments from the regulatory bodies in Europe and several of these, including SKI, have formed a group, which responds to this request. So far a few important chapters in the EUR document, rev. B, have been reviewed and comments have been given to the EUR project.

4. Regulatory views on competence requirements and associated research

In Chapter 2 above regulatory response to the IAEA Safety Convention was mentioned with particular reference to items that affect the industry. Other areas, in which improvement on the regulatory side is considered important, include the following.

The International Commission for review of Swedish Nuclear Regulatory Activities pointed out that the regulatory requirements were not always clear and co-ordinated in the Swedish system. The Commission also pointed out that in particular SKI needed to define regulatory tasks better and to implement a modern internal quality assurance system. Extensive work has been done to clarify the missions and tasks of SKI, to issue general safety regulations in co-ordination with the Swedish Radiation Protection Institute and the Rescue Services Agency, and to define a new regulatory role with the focus on the activities and processes of the licensees. The implementation of the new regulations and the development and implementation of the new internal quality system of SKI will have high priority around year 2000.

Today, much of this work has been carried out. For example, SKI is promulgating new regulatory requirements that will emphasise the demand for qualified personnel in several areas. A shortage of qualified, university-trained engineers exists in fields such as structural integrity, reactor physics, reactor technology, and instrumentation and control systems.

The Government has realised the need to support recruitment of SKI personnel with a strategic competence. Salaries are being offered that are competitive with those of the Industry. Furthermore, stimulating working conditions with real possibilities for the staff to take responsibility are being created through the new SKI quality system and planning process.

In the process of defining the role of SKI it has established the principle that SKI staff shall have long-term tasks including responsibility for safety related research projects. To transfer responsibility for the research to an external “Technical Support Organisation” is not the way to go. One must also avoid that qualified staff members become preoccupied by event triggered activities.

The following sections summarise some aspects of SKI’s involvement in regulatory and safety research. The activities are most often conducted in co-operation with the industry, and they also support an optimistic view of the possibilities to sustain recruitment and competence.

4.1 Safety research at SKI and universities

Since many years, SKI is sponsoring research in safety analysis within the framework of its Research Programme. The Regulator supports a Chair in Nuclear Power Safety at KTH, the Royal Institute of Technology in Stockholm. The professor has an internationally leading role in severe accident experimental research and analysis. His work is also connected to severe accident analysis that is continuously being carried out by an SKI/Industry group for the purpose of monitoring the status of mitigating features at the operating plants in Sweden. Severe accident phenomena offer opportunities to find interesting topics for PhD research, and this attracts many PhD candidates who may later be available for recruitment to the industry.

Behavioural sciences are recognised as being very important in safety analysis. Today, groups engaged in Human Factors Research and Analysis exist at all plants. Their work is particularly important since this kind of interaction proves to constitute the root cause in a majority of disturbances at the operating plants. A professor in “Nuclear Safety and the Interaction of Man, Technology and Organisation” at the University of Stockholm is sponsored by SKI and is leading several research projects with a bearing upon the current problems.

Some important international co-operation projects are supported, such as the Nordic Collaboration project, NKS. In this project the reactor safety issues treated are: risk evaluation, strategies for safety, severe accidents and emergency planning. Furthermore, the OECD Halden project is supported by SKI in fuel safety and man-machine problems.

4.2 Swedish Centre of Nuclear Technology

A main activity of the Centre is to support PhD candidates (with scientific advice and economy) in topics related to nuclear technology. While initially solely a KTH-oriented organisation, the Centre was recently transformed into a national undertaking. Thus, today it supports many seats of learning at Swedish universities and institutes of technology, including nuclear technology related topics at Chalmers Institute of Technology and Gothenburg University, Linköping Institute of Technology, Uppsala University, and Luleå Technical University. This is illustrated in Figure 3. At present, around a dozen young engineers are engaged in PhD projects sponsored by the Centre at the various institutions, or have already passed examination.

The research director of SKI and technical managers at the NPPs and ABB Atom are members of the Board. These organisations are the sponsors of the Centre. The Board also includes professors in the key research areas from KTH, Chalmers, and Uppsala. A director conducts the day-to-day business of the Centre and is also responsible for taking initiatives towards its development according to general directions and approval by the Board.

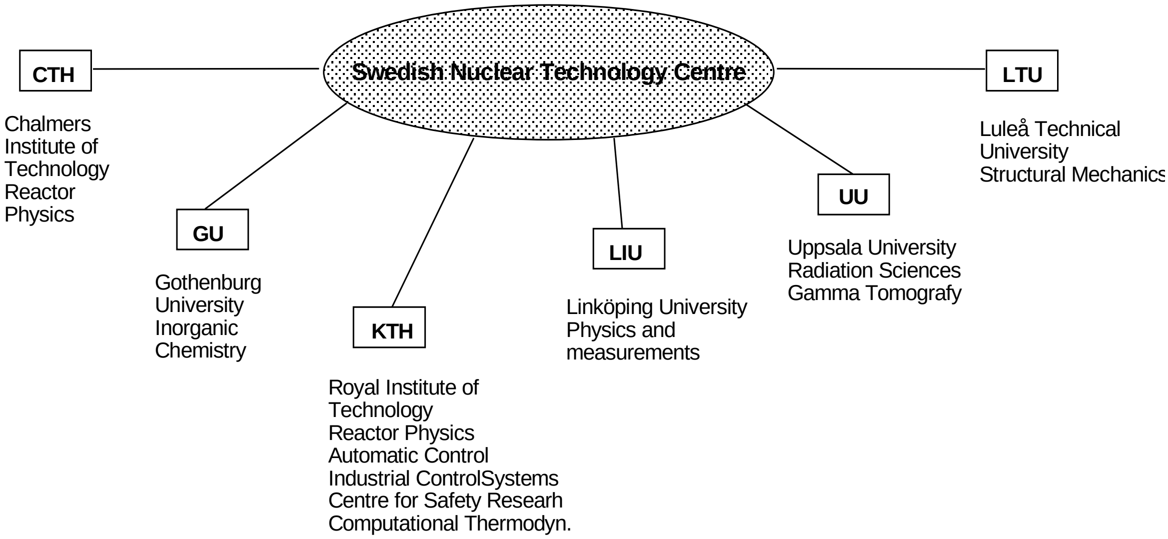

Fig. 3: Overview of support to Swedish universities and institutes of technology (April 1999)

A presentation of the Centre was given at an IAEA conference (Tirén, 1994).

4.3 Further strategic plans

The regulatory task is, of course, the main responsibility of SKI. In this context the competence must be maintained in the long-term perspective. In the new situation described above with new threats such as deregulation and the threat of nuclear phase-out, it is of vital importance to investigate the competence that must be available in the future. This investigation will start before the end of this year. A number of questions need to be answered:

- What competence is unique, such as reactor physics, and less unique, such as material science? Unique competence must be supported with teaching capability.
- Furthermore, where should the competence centres be situated, at the universities or with qualified consultants?
- To what extent can SKI rely on competence outside Sweden?

The strategy to maintain competence will be different depending on the answers to the above questions.

5. Conclusions

This paper clearly demonstrates that in Sweden, both the regulator and the industry are vigorous in their efforts to safeguard the competence needed for safe operation and maintenance of the nuclear power plants into the 21st century. SKI has responded to the IAEA Safety Convention. Room for improvement of regulatory activities was identified in some areas, and systematic measures have been taken. This includes the promulgation of new regulations, improving competence in the regulator's key engineering staff and assigning responsibility for safety related research to them, and implementation of a new internal QA system. Much of the new directions were designed to ensure that the licensees will continue to be able to carry full responsibility for the safety of plant operation and maintenance. This implies that efforts are made to ensure that highly qualified engineers in key technical topics continue to be available.

The industry also responds vigorously to these challenges. Many initiatives that will stimulate recruitment and boost competence are described above. This includes research projects that are often conducted by the regulator and the industry in co-operation.

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PROMOTING A LEARNING CULTURE TO MAINTAIN THE NUCLEAR SAFETY COMPETENCE OF AECB STAFF

Al Omar, Senior Technical Trainer
Nicole Bélisle, Technical Trainer
Ian Grant, Manager

Technical Training Group
Atomic Energy Control Board
280 Slater Street, Ottawa, Ontario CANADA K1P 5S9
grant.i@atomcon.gc.ca

Abstract

In the Canadian regulatory approach, the safe operation of a nuclear installation is primarily the responsibility of the operator. The mission of the Atomic Energy Control Board (AECB) is to ensure that the use of nuclear energy does not pose unnecessary risk to workers, the general public and the environment. The AECB fulfils this responsibility through a comprehensive licensing framework in which compliance with regulatory standards and requirements is assured through systematic safety assessments, inspection and enforcement. These responsibilities require regulatory staff with specialized academic backgrounds and work experience related to the industry.

In the past, the AECB readily attracted and retained the qualified personnel needed to ensure nuclear safety competence. However, several factors are now altering this situation. Anticipated retirement in the years ahead among the current generation of staff will result in significant losses of corporate knowledge and experience. In addition, the stagnation of the domestic nuclear power industry has impacted significantly on the recruitment of suitably qualified replacement candidates. Many Canadian universities have had to reduce their nuclear programmes as fewer undergraduate and postgraduate students choose a nuclear career option.

In these circumstances, maintaining the AECB's nuclear safety competence requires a more systematic and deliberate approach. This paper describes the measures that the AECB has taken and is planning to take to promote a learning environment, and to assist staff in establishing and maintaining their knowledge and skills.

1. Introduction

This paper reviews trends in the Canadian nuclear business environment and employment demographics, and discusses the implications of these trends with regard to maintaining safety competence of the Atomic Energy Control Board (AECB), the Canadian national nuclear regulatory body. The importance of organisational learning to safety culture is discussed with a view to identifying solutions. The paper finally describes current actions endorsed by the AECB and possible future measures to maintain nuclear safety competence.

2. Background

On its creation in 1946, the AECB received a mandate to control and promote the use of nuclear energy, a mandate that has since evolved to focus on ensuring that the use of nuclear energy poses no unreasonable risks to health safety, security or the environment.

Originally, the regulatory system was simple. The Board (the decision-making body of the AECB) consisted of a panel of appointed members which oversaw nuclear activities and applied controls directly. At that time, the two major sectors of the industry were research and uranium mining, and both were capable of running their own businesses without the interference of the AECB. Each of these two industries was represented by a Board member appointed by the government. The role of the AECB was therefore contained in the provision of policy advice. Consequently, the staff population was intentionally kept at minimum; that is, three employees (Sims, G.H.E., 1981.)

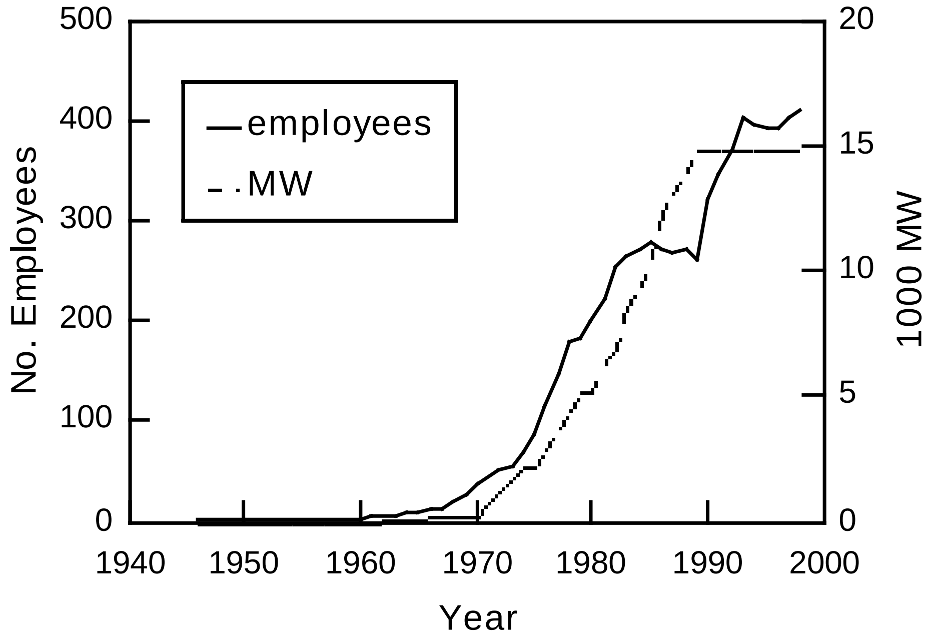
When Canada in the mid 1950's seriously pursued the development of nuclear power generation based on natural uranium and heavy water, several related industries flourished, from uranium mining to reactor component manufacturing. The AECB regulatory system therefore was enhanced to include technical assessment and evaluation of licence applications by qualified scientific advisers. It was natural that such scientific advisers were recruited from the nuclear industry of the time. However, only in the early 1960's that the number of employees began to surpass three.

The combination of small organisational size and technological complexity often fosters the evolution of informal or craft-style organisational structures and processes (Daft, 1995). From the outset, the AECB adopted a non-prescriptive approach to regulation. Technical authority was vested in the small but growing cadre of knowledgeable advisors on whose competence and professional judgement the AECB relied.

By the 1970s, the AECB was an organisation of some 50 staff overseeing the developing nuclear industry. From that point began a period of rapid growth, parallelling the growth of the industry itself. Employment doubled, and doubled again, reaching a complement of more than 400 permanent staff by the early 1990's. Figure 1 depicts this increase.

During this period, the AECB tended to rely on recruiting experienced specialists for its expanding organisation. Against the backdrop of innovation and development of nuclear science and technology, the AECB was able to attract suitably qualified scientists and engineers. These experienced individuals were aware of the safety aspects of nuclear technology but their knowledge was not necessarily well-documented, for much of it gained from their own involvement earlier in their careers. They maintained their competence by communicating and interacting with their counterparts on the licensees' side, attending conferences, and self pursuit of advances in the field of their expertise. A legacy of these years is the lack of a formal learning environment.

Figure 1. **AECB Staff Growth vs. Industry Growth**



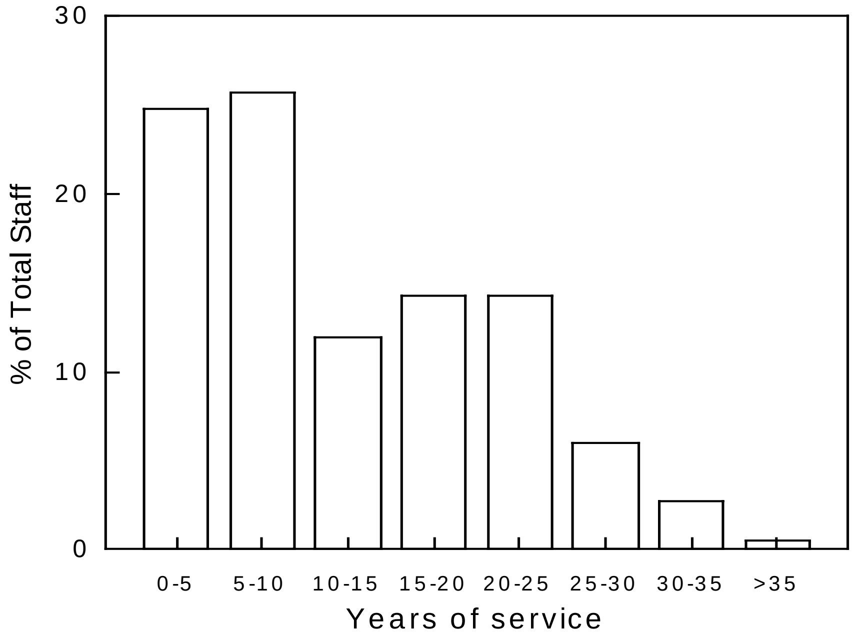
The majority of staff members who joined during this period remained with the AECB for the remainder of their careers. This pattern resulted in low staff turnover over a period of nearly thirty years.

Today, almost one third of AECB staff have more than 20 years of service and will be eligible for retirement within five years, as Figure 2 illustrates. In addition, the imminent departure of the baby boomer generation exacerbates this situation by posing the possibility of the loss of a major wealth of knowledge and organisational competence in the next five to ten years.

The climate in which the AECB currently operates, however, is much changed from the early years. The state of the nuclear power industry is an important factor. The most recent power plant completed in Canada came on-line in 1992. Some older plants have been closed or mothballed and no new construction is being considered. The electricity-supply industry is undergoing commercial deregulation and reorganisation. Government cuts in R&D budgets are reducing the scientific and technical infrastructure. Adding to future uncertainty, reports of management deficiencies at some utilities have shaken public confidence and also have raised questions about the performance of the regulator.

The stagnation of the industry is having a significant impact on the availability of suitable recruits. The perception of dead-end careers in the nuclear industry has resulted in several universities reducing or closing their nuclear engineering departments as fewer undergraduates choose a nuclear career option. This is affecting the quality and availability of suitable personnel.

Figure 2. **AECB Staff Demographics**



The fact that parts of the industry are facing similar, or even more serious, demographic issues among their employees' poses concerns not only from a regulatory point of view, but also with regard to pressures in a limited employment market.

Addressing these issues will necessitate a more deliberate approach to maintaining competence than was practised in the past. Even in recent years, younger recruits have received little formalised training, and turnover among this group has been relatively high. There is a need to employ more young staff, for systematic training and development, for succession planning and for documentation to maintain corporate knowledge. This will place a new burden on corporate training resources.

3. What should be done–theories that exist

Having identified the background and the issues, we ask ourselves what should be done in order to promote nuclear safety competence? While the literature offers endless possibilities, our focus will be on those areas which fall under the umbrella of "promoting a learning culture."

3.1 Safety culture and the regulatory body

In its June 1999 report on the role of the nuclear regulator in promoting safety culture, the Nuclear Energy Agency's (NEA) refers to safety culture as "an organisation's basic safety values, attitudes toward conservative operation, quality, professionalism, continuous learning and improvement processes as well as an environment in which workers are free to raise safety concerns without fear of retribution." The NEA believes that it is the regulatory body's responsibility to promote safety culture through its own example and its professional conduct with the operators (Murley, June 1999).

Another definition of the safety culture of an organisation is expressed by the Institution of Occupational Safety and Health (IOSH) as "the product of individual and group values, attitudes, competencies, and patterns of behaviour that determine the commitment to, and the style and proficiency of, an organisation's safety programmes" (IOSH, 1992).

Therefore, an organisation deemed to have a positive safety culture when it consists of competent people with strongly-held safety values which they put into practice. Although most people possess the essential values and intentions, their actual behaviours may not necessarily support a total safety culture.

One way of developing and sustaining a supportive safety culture relies on a better understanding of human behaviour. By applying the principles of behavioural science and person-based psychology, one can promote specific attitudes in individuals that will encourage safety behaviour. Ultimately, through effective performance management techniques and worker empowerment, a truly positive culture, one which values safety, can be formed.

3.2 Effective performance management techniques

While there may exist numerous techniques which could be utilized to promote nuclear safety competence, a few will be highlighted that would merit attention.

Competency profiles and intellectual capital

Parry describes competency as "a cluster of related knowledge, attitudes and skills that affects a major part of one's job (i.e., one or more key roles or responsibilities), that correlates with performance on the job, that can be measured against well-accepted standards, and that can be improved via training and development" (Parry, 1998).

As mentioned in Section 2 above, increased retirements, stagnation of domestic nuclear power industry, and the reduction of university nuclear programmes will soon lead to significant loss of corporate knowledge and experience. In addition, external pressure on nuclear safety is asking for a workforce not with more knowledge or skills, but with competencies.

The idea is to build and maintain highly motivated and competent workforces. Therefore, establishing specific job competencies would provide organisations with a useful tool for assessing the knowledge, skills, abilities, and behaviours required for successful performance. In addition, it allows for a more cohesive organisation, where collective wisdom is the key to maintaining the organisation's memory. Manville and Foote point out the importance of core competencies, and the role they play in the sharing of knowledge. "The power of core competencies is harnessed by creating informal networks of people who do the same or similar kinds of work ... Practitioners who are exposed to the same class of problem often develop a sense of mutual obligation to help one another, because doing so helps each one individually. Professionals share in their understanding of the issues and solutions by participating in the network" (Manville and Foote, 1996).

Succession planning and career paths

Intertwined with the idea of competency profiles and intellectual capital, is the notion of succession planning, and the development of career paths. Due to the decrease in nuclear-related positions, there needs to place more emphasis on the development and training of newly hired personnel. Along with the traditional didactic teaching methods, new pedagogies need to be implemented such as case studies, on-the-job, self-directed, mentoring and customized training.

Toward a learning organisation

The topic of organisational learning has gained much attention, especially over the last decade. In place of the traditional bureaucratic model of organisations, the learning organisation model calls for an organisation that is open to changes in its structure, and in which workers can contribute as creative participants utilizing their learning capabilities (Sugarman, 1999).

The term "learning organisation" broadly encompasses the concept that successful adaptation to changes and uncertainties is most likely to occur when sufficient and appropriate learning tasks are placed throughout the organisation (West, 1994). Also, a learning organisation is that which is "skilled at creating, acquiring, and transferring knowledge, and at modifying its behaviour to reflect new knowledge and insights" (Garvin, D.A., 1993). Nonakan and Takeuchi's learning organisation model focuses on how knowledge is used and produced. "By organisational knowledge creation we mean the capability of a company as a whole to create new knowledge, disseminate it throughout the organisation, and embody it in products, services and systems" (Nanoka and Takeuchi, 1996).

The learning organisation is that which itself learns, and encourages learning among its staff. It promotes exchange of information between employees which, in turn, creates a more knowledgeable workforce. This results in a flexible environment where individuals, through a shared vision, will accept and adapt to new ideas and changes.

In essence, organisational learning implies that a new philosophy of management is required. One which encourages openness and reflectivity, and accepts errors and uncertainties. Members need to be able to question decisions without fear of a reprimand. In this type of environment, the leader's responsibility is to encourage learning at all levels of the organisation, so that members can learn from each other. Workers become responsible for their actions, empowering them in their milieu. Senge states that in the learning organisation, leaders are designers, teachers, and stewards. These roles require new skills: the ability to build shared vision, to bring to the surface and challenge prevailing mental models, and to foster more systemic patterns of thinking. In short, leaders in learning organisations are responsible for building organisations where people are continually expanding their capabilities to shape their future-that is, leaders are responsible for learning (Senge, 1990).

4. Initiatives to maintain and develop safety competence

AECB management has recognized the challenges posed by staff demographics and the changing business climate and have accorded high priority in the strategic plan to several initiatives aimed at improving safety culture and creating a learning organisation. These are discussed briefly below.

4.1 Reform of human resources framework

Given the anticipated retirements and the probable need to hire young and relatively inexperienced staff, an initiative is underway to reform the human resources framework in order to create a learning culture in which staff have training and development opportunities to acquire the needed knowledge and skills on a continuous basis. Both professional and people skills are needed.

4.2 Learning policy

To support the human resources reform initiative, the AECB management has formally adopted a “learning policy.” The principal objectives of this policy are to:

- Develop employees so they are capable of carrying out their current job responsibilities to a corporately established level of competence.
- Position the organisation and its employees to meet future business requirements and challenges.

4.3 Increased effort in staff training and development

T1o further support and implement the human resources reforms and the learning policy, increased effort and resources are being devoted to training and development. The intention is to implement technical training for staff following the well-known Systematic Approach to Training (SAT) methodology. In the SAT methodology, the need for training is assessed based on job and task analyses, and training is designed, developed, implemented and evaluated to provide learners with the knowledge and skills required for effective performance.

4.4 Training curriculum and training needs analysis

To support the learning policy and SAT, the AECB has drafted, through a “Table-Top Needs Analysis,” a master list of functions exercised by each line division in the current organisation, and the main knowledge and skill areas that each consequently requires. Taken collectively, these profiles give a matrix of required knowledge and skills for the organisation as a whole. Table 1 illustrates the main headings. This matrix defines the overall training curriculum against which specific needs can be identified and prioritised annually.

Table 1. **Corporate matrix**

General Technical
Facilities Management & Operations
Laboratory Operations–Specific
Mining Operations–Specific
Physics & Sciences
Facilities Engineering
Safety Evaluation
Radiation & Environment Protection
Non-Proliferation & Safeguards
Quality Management
Performance Evaluation Techniques
Training Technologies
Programme, Project & Research Management
Financial & Business Management
Contract Management

4.5 Competency profiles

The AECB has developed competency profiles for individual management positions and, to date, for some technical position, notably reactor project officers and field inspectors for radioisotope licensees. Table 2 exemplifies the main competencies for the reactor project officer. Competency profiles serve as standards against which individuals' skills and knowledge can be assessed, in order to develop training and development plans. The intent is to develop competency profiles for each main "job-family" in the line organisation.

Table2. **The project officers**

Technical Knowledge & Expertise
Communicating Effectively
Teamwork
Analytical Thinking and Problem Solving
Self-management
Managing Projects
Leading and Developing Others
Dealing with Difficult Situations
Assessing Safety
Monitoring Licensee Compliance
Assessing Licensing Documents
Enforcing Licensing Requirements

4.6 Examples of training

Current examples of training being delivered to AECB staff include:

- Training on the new Nuclear Safety and Control Act (NSCA), thereby assisting a smooth transition to the new regulatory requirements. All AECB staff received training on the NSCA, for a total of six person-years of trainee time.
- A similar effort is planned on training on the regulations authorised under the NSCA.
- Training on audit and investigation functions to reinforce compliance practices.
- Training on radiation protection standards and practices.
- Management and administrative training to support the competency profiles and strategic direction.

4.7 Other measures to maintain nuclear safety competence

Regulatory document production

To support the introduction of the new nuclear safety legislation, the AECB is systematically producing and updating regulatory policies, standards and guides. The intent is to develop a framework that reflects current organisational knowledge as well as best international practices. While such a framework of regulatory documents by no means eliminates the need for professional judgment by staff, it will serve to guide future regulatory decisions.

Certification of inspectors

The forthcoming legislation provides for formal qualification and certification of staff in specific job functions such as inspectors. When competency standards have been defined and the training curriculum is well established, the AECB may in future introduce formal certification for competence for such positions.

Capturing corporate knowledge

The corporate memory could be captured not only in regulatory documents but also in training material. Since 1993, the training sections within the AECB have produced a multitude of training materials, ranging from overview presentations to full courses, that are based on the knowledge and experience of senior staff. This material, if formally catalogued and continuously updated, will prove useful in training new personnel.

5. Discussion

While measures discussed above address the current trends in employment demographics, thei implementation puts a new burden on training resources. The development of systematic programmes for staff training, together with the necessary curriculum and course materials, is a costly and time-consuming exercise that cannot be done overnight.

Strong incentives exist, therefore, to find solutions that reduce the cost and time taken to develop and deliver effective training. Some alternatives that should be explored include:

Co-training with industry on common "technology" topics

In some scientific and technical areas, the required knowledge at a basic or fundamental level is common to both the industry and the regulator. In such circumstances, it might make sense for the regulator and industry to collaborate whether by using existing training opportunities or by co-developing new courses. To preserve independence, this could also be done at arms length by supporting universities and technical training institutions.

Collaboration with other national nuclear regulatory organisations:

Different nuclear regulatory bodies have adopted various approaches to staff training and development. Sharing of best practices in this area could assist in creating rapid improvement. Another area of possible collaboration is personnel assignments to enable staff from one agency to gain experience in specific areas, such as plant decommissioning.

Development of international training standards & courses

Considerable focus has been placed on development of international standards and criteria for training of operating staff for nuclear power plants. Updated standards and criteria for training of regulatory staff would also be helpful, as would be the availability of training courses.

6. Conclusions

Current trends in the Canadian nuclear industry and employment demographics pose several challenges to the AECB in maintaining its nuclear safety competence.

Creation of a formal learning culture is seen as key to acquiring and maintaining the required staff competence.

Initiatives are under way at the AECB to reform the human resources framework and to increase resources applied to staff training in order to foster a learning culture.

The cost of training programme development is an incentive to adopt where possible collaborative approaches to developing standards, criteria and training and development opportunities for regulatory staff.

Acknowledgements

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TRAINING SYSTEM ENHANCEMENT FOR NUCLEAR SAFETY AT PAKS NPP

István Kiss
Paks Nuclear Power Plant
P.O.B 71. 7031 Paks, Hungary
KISSI@NPP.HU

Abstract

Paks Nuclear Power Plant is the only commercial nuclear facility in Hungary, which has been operational since 1982. The over 15 years operation of the plant can from all aspects be considered as a success, to which the well qualified, competent staff significantly contributes. Like other N-plants, Paks NPP is also exposed to major challenges due to plant ageing and changes in circumstances that affect the operation. The management focusing on maintaining nuclear safety launched an overall programme to upgrade quality of personnel training and to improve its infrastructure. Though this programme has successfully finished with visible proofs, further actions to develop a reconsidered human resource policy is needed so that the plant would successfully stand against the challenges of the 21st century.

1. Introduction

Paks Nuclear Power Plant is the only commercial nuclear facility in Hungary, which has been operational since 1982. The electricity produced with the four WWER-440 units cover 38% of the domestic needs. Though, to date, this is the cheapest and cleanest source of energy used in the country, the plant is to face major challenges so as to maintain competitiveness and share on the market.

Paks NPP owns good reputation in the community of nuclear operators, primarily due to its extraordinary operational and safety records. Maintaining these high performance indicators is becoming more and more difficult. Besides its typical “mid-age” problems, such as declination of hardware technical condition or personnel ageing, the plant is to comply with both the new requirements and expectations of the new restructured Hungarian economic environment and with the critiques of a not-exactly nuclear friendly public.

2. Training system

2.1 Historical overview of the training system

Personnel competence is one of the most important of the many factors, which altogether allowed for the safe and efficient operation of the plant so far.

Participation in the investment programme of the most state-of-the-art energetic project at the end of the ‘70s was a very attractive opportunity for both new vocational school, university graduates and skilled personnel working for conventional plants, so Paks NPP Company could recruit its employees from an excellent and extensive stock.

Initial training of the personnel began abroad, but later the in-site training centre established parallel to the plant’s construction took over and continued to deliver training ever since.

The training system and tools developed at the beginning of the ‘80s complied with the requirements of those times. Training of the operations personnel was aided at an extremely high standard by the full-scope replica simulator established in 1987.

2.2 Problems of the 1990s

By the beginning of the ‘90s, problems related to human resources arose. Part of these problems has been already cured by the training system reconstruction, but the rest may only be solved with a carefully considered human resources management concept for the whole plant life-cycle and the consistent implementation thereof.

The most typical of the problems are:

- The generation commissioning the plant is becoming the drop out of the front line mostly because of retirement, but also due to carrier promotion from operations and maintenance to management or administrative posts.
- Along with plant ageing and the consequently increased contractor involvement, the available training infrastructure is no longer capable to efficiently undertake training tasks for the maintenance staff.

- The training system based upon part time trainers invited primarily from the plant is capable of handling neither training tasks related to major technical upgrading and reconstruction programmes, nor maintenance of training programmes and materials.
- Attraction of the plant considerably declines due not only to the public environment hostile to nuclear industry but also to the extinction of the distinguished pay conditions.
- Downsizing and employment freeze typical to the last decade limits the potentials for good individual carrier development, there is no new staff being raised, passing of knowledge and experience to the younger generation is endangered.
- Frequent reorganisations undermine employees' feeling of security, hence deteriorating corporate identity and commitment.

2.3 Training upgrading activities in the 90s

To upgrade quality and conditions of training, the plant initiated a large-scale programme in 1994 with assistance from the IAEA, and involvement of both international and domestic experts. The Hungarian Model Project managed an overall development programme for training called "Strengthening Training for Operation Safety at Paks". The project fulfilled all expectations. By April 1997 a world-wide unique Maintenance Training Center had been built, the training programmes of operational and maintenance personnel reworked using the principles of the IAEA promoted SAT (Systematic Approach to Training), and the plant made considerable steps toward an enhanced safety culture. Besides, training staff tripled, in nuclear safety significant posts new training programmes and materials were developed and the new, competent trainer staff is capable of training the plant personnel on changes deriving from safety and technical upgrading programmes underway, meeting all expectations.

2.4 Questions left for coming years related to personnel training

In spite of the major development programmes as mentioned above the plant management may not sit back. The Government promoted energy-liberalisation programme forces owner decisions that have impacts on training as well. The cutback of expenditures and the increase of cost efficiency require the creation of an efficient organisation. The re-organisation itself poses major training tasks due to the changes in job-specific responsibilities and accountabilities. The plant management should put stress and keep focus that the competence of the staff due to this restructuring process may not decrease even temporarily and maintenance of nuclear safety always have priority above other considerations.

Already today, contractor staffs play considerable role in the plant's life and work and this shall become even more characteristics in the future. Consequently, the control of their qualification requirements and competence shall be a major component in both productivity and safety.

3. Conclusion

Taking the changes already underway into consideration we must conclude that the management, in spite of the upgrading of personnel training of the last decade, must have and implement a carefully developed human resource management concept that provides a long-term solution.

ASSURING NUCLEAR COMPETENCE IN THE NETHERLANDS

Robert J. van Santen
Head
Nuclear Safety Department (KFD)
Ministry of Social Affairs and Employment
The Netherlands

Introduction

Assurance of nuclear competence is highly depended upon the national situation. Furthermore, the justification and evidence results, if agreed on the definitions and scope, are normally expressed in more in qualitative terms and less in quantitative terms. A cautious approach is recommended when quantitative results become part of the outcome of this workshop. Results and suggestions on levels of competence, policy and practices can only be compared with almost identical situations.

Situation in the Netherlands:

Scope nuclear programme

The assessment of the nuclear competence e.g. the regulatory practices in the Netherlands require some understanding of the situation in the Netherlands, the cultural and social context in which nuclear energy is applied.

The nuclear sphere of activity in the Netherlands is characterised by the size of nuclear programme:

- small nuclear programme (1 PWR operating, 1 BWR in decommissioning, 3 research reactors, 1 enrichment plant, 1 longer term waste storage facility and 1 nuclear laboratory);
- small nuclear regulatory authority, connected to 2-4 ministries (KFD ca. 12 experts, 4 inspectors and in total ca. 22 people);
- scale of nuclear supporting industry also small (no large designers).

Future in relation with nuclear programme

A complicating factor in the near future is the closure of the only operating nuclear power plant. The parliament has decided to permanently close down in end 2003. This will probably cast its shadows forward long before that actual date is reached. The early closing down decision was taken not for technical reasons, but because of the political/social situation, as a matter of fact right after the end of the large and complex modification project.

Example of recent experience

Originally based upon the 10 years safety evaluation a modernisation project in the power plant required during several years a high manpower level at both sides (the plant and the KFD), with associated high level of competence of the involved staff. This was reached not by specific education, but much more by the exchange of know-how and experience of the experts in safety developments from the involved foreign experts, notably from Siemens and AVN, as Borssele is a Siemens/KWU plant.

Nowadays, with that project ended, activities for safety evaluation and field inspection and audits are down at a normal level. However, for our current level of nuclear activities, nowadays the IAEA and others suggest (in the Vienna Convention, April 1999) a larger minimum regulatory body.

Rules and regulation based on IAEA

The small size of the nuclear programme and the KFD in the Netherlands made the choice for the IAEA system of Safety Series, to arrive at clear, complete, balanced and generally accepted rules and regulations understandable. The availability of a good rules and regulations system is considered a sign of effectiveness of the RA. But the process to arrive at a system that also is adequate legally and useful in enforcement actions is another matter. It requires a detailed amendment job, involving hundreds of man-hours of highly specialised experts. The result is a regulation system, and a more or less a highly knowledgeable staff, that was and still is forced to become acquainted with the background of the how and why of the rules. That amendment process is still going on because the IAEA publishes revised or new requirements or safety guides. Also, these rules and guidelines must be complemented by lower level working documents such as engineering codes and specific subjects as grading. Also in this case every rule and every guideline is in-depth discussed with the licensee. Involvement is a basic element for motivation to adhere to it and leads to higher competence.

Regulatory body conditions

In the Netherlands, the small nuclear electricity-producing programme had two overall main dimensions:

- a comprehensive nuclear designer and manufacturing industry do not exist nowadays;
- the size in manpower of the regulatory body is also very limited.

These effects are handled by the KFD in the following ways and it is our policy to maintain these ways and level in the 21st century, at least with the current programme.

Regulatory policy

The policy of assuring competence of the RA and the Licensees in the near future is based on considerations as:

- Both are explicit responsible for maintaining the necessary competence for their own existing staff, and the RA watches over the effort of the Licensees.
- Incorrect assessments are not tolerated, because of the political sensitivity towards every thing that relates to nuclear.
- Sufficient budget should be available for foreign assistance.

Awareness of small size

We are aware that we have to compensate for the small permanent size:

- a budget is made available that allows us to contract three man-years of capacity on a yearly basis.
- another budget is made available for contracting out to technical support organisations in case of specific problems of nuclear safety.

This however does not relieves the KFD of the obligation to take care that sufficient general and specific knowledge of all nuclear safety aspects is and stays available within KFD. Our specialists ought to know what they should investigate more deeply and what the aims and expected type of results are. A positive element is the fact that the KFD indeed has considerable nuclear knowledge. Most staff members have long time experience and a high education, which is kept up-to-date by an "education permanent" programme.

Future challenge in respect to competence

The Nuclear Safety Department (KFD) is 31 years old. The average age of the technical staff is 53. Several staff members have been in the organisation for 15 to 30 years. Some of them will leave KFD soon. So KFD has a serious ageing problem. Because of the closure of the only power plant (end 2003) it will be hard to find replacement for diminishing knowledge of senior staff for such a short period.

Responsibility

This particular aspect is essential in the set-up in the Netherlands. The relationship is characterised by an emphasis on responsibilities. Responsibility for reaching sufficient nuclear safety rests clearly with the licensee and the responsibility to watch over it rests with the KFD. The KFD has a non-prescriptive attitude and most of the assessments, checks and inspections are directed at system level, hardware as well as organisational. This behaviour has a strong influence on the approach towards assessing the effectiveness of the regulatory practises. Quality Management on both sides plays an important role in this area.

Society aspects

A specific point is the very negative public opinion on nuclear energy in the Netherlands. So, neither the licensee nor the regulatory authorities can risk a negative appearance in public. This also has a positive and a negative side: positive because both parties take considerable effort in investigating and explaining to the other party the necessity or non-necessity of certain measures. Requests from the government are not just “orders” but must be fully accounted for (convincible). At the negative side this relationship could appear to an outsider as rather close.

(In)dependency

In the light of the situation as sketched above, some characteristics are prerequisites for the competent regulatory organisation:

The independency of the KFD itself is sufficiently established in legal documents. The independence from promoting elements in the licensing sphere changed recently. The ministry of economic affairs was leading in the license process. This leading position changed summer 1999 to the ministry of environment.

The independency of the KFD is underlined by being provided with the tools especially the financial tools, to perform the job, especially aimed at contracting out nuclear safety review and evaluation work to organisations like AVN in Belgium and GRS in Germany. However, to the minister, the parliament and the society, we are responsible and should be able to prove that we have sufficient competence to do our job.

The safety policies and objectives are in general initiated by the KFD, discussed on policy level with the ministry of environment and also with the licensees. Every action from the government that influences the operation of the nuclear power plant is also in extenso discussed with the licensee, while maintaining explicitly the basic independent and questioning attitude that should be expected of a regulatory body.

With its plus and minus sides, there have never been really doubt at either the licensees or the regulatory authorities, about the clear separation of responsibility between licensee and government. And motivated by these often-intense discussions, the competence level is maintained and even increased by specific education, by study and by international contacts of the staffmembers of the KFD and the Licensee.

Internal QA

An important part of the assurance of nuclear competence of the nuclear parties is the quality system around the internal regulatory process within the KFD. This regards the quality of working and the evidence of fulfilling the tasks connected with the nuclear safety issue. The KFD became convinced of the importance of this element years ago.

Together with felt need to show the outside world and the own ministries that the nuclear safety department “ is doing their job”, transparency of the organisation and the various working processes is essential together with the provision of actual, objective evidence. These requirements have led to the development of an internal QA system at the KFD.

This QA system has now reached the end of the first phase of development and implementation. Although based on ISO 9001, which could be read as a standard with a large tolerance in actual reached quality level, the KFD has interpreted it as a high level high knowledge based system, with a surprising variety of complex processes and very structured administrative systems. On the 16th of September this year we got our certificate of ISO 9001. ISO is chosen also because it is a general well-known system to the public and to the government.

Foreseen is finally a nuclear safety oriented audit on the regulatory authorities in the Netherlands that may take the form of an IRRT mission.

It is mainly due to our shortly foreseen transfer towards the ministry of environment, which leads towards practical rearrangements and due to the planned strong reduction of the nuclear programme that an IRRT-like mission has not been firm planned yet.

International relations

The last parts of the assessing of the assurance of the competence are the international contacts and working programmes within the western world. Besides the reason for international or European contacts as mentioned before, the exchange of knowledge and practices because of these contacts are an essential complement to reaching the necessary nuclear competence levels of nuclear safety.

The scope and the quality of international are certainly seen in the Netherlands as contributing to the assurance of competence of the regulatory authority and licensees.

EXPERIENCE WITH GENERATIONAL CHANGES AND ENHANCEMENT OF COMPETENCE AT THE OECD HALDEN REACTOR PROJECT

Outline Of Personnel Dynamics And Practices At Halden

C. Vitanza*
Manager of the
OECD Halden Reactor Project
Le Seine St-Germain
12, boulevard des Iles
F-92130 Issy-les-Moulineaux
carlo.vitanza@oecd.org

Introduction

The OECD Halden Reactor Project started its operation 40 years ago. Following a construction period of four years, the reactor, a boiling water type (HBWR), went critical for the first time on the 24th of June 1958. Almost immediately an OECD Project was prepared and launched around the test capabilities that the facility was offering. Forty years later, the Halden Project is still in full operation and in rather good health. During this time period it has obviously undergone many changes and the programme has continuously adapted to the new demands posed by the nuclear community. At the same time, however, the Project has remained faithful to its roots. The trust of the international community – and of the staff members – about the Project's ability to reach long term goals is also based on this mix of tradition and innovation that characterises this organisation.

It has often been asked what is the “secret” of the Project, i.e., how has it been able to maintain a successful operation over a long period of time, especially when difficulties and decreasing funds affect the nuclear research community. The Project prefers not to answer this question, as indulging on qualities may be the first step towards decline. Moreover, there isn’t an answer to it – or at least the Project doesn’t have one.

Together with programmatic changes, considerable personnel changes have taken place at Halden, especially in the last decade. This is not surprising, since the personnel that were employed in the first years of the Project have gradually reached retirement age. This evolution is reflected in the average age of the employees, which was 48 years in 1990 and is 39 today. The present age distribution exhibits a peak in the age interval 25-35 years, while the fraction of personnel beyond 55 is now 12%. Where it concerns management (incl. the division heads), the average age is 46.

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* Paper presented by Lise Moen, OECD Halden Reactor Project.

As always when statistics are involved, one should be aware of some conditions. Here, one should observe that the retirement age in Norway is 67, which is appreciably higher than in many other countries (the employees can actually continue until the age of 70, which is not unusual). These personnel changes have taken place gradually and in this process care has been taken in transferring the skills of the experienced generation to the younger one. Incentives for early retirement have never been used at Halden, that is, it has never been a policy to "forcedly" renew the ranks, as it is felt that this would have a negative impact on personnel morale and may – at the end – work against its aim. We feel that the staff should always trust their company that they will not be dismissed after having done their best for many years and when they are still performing a good job. The assumption is that the employees do "their best" all the time: by assuming this – and making it part of the normal way of thinking – the assumption becomes reality. Or this is, at least, the experience that the author of these notes has.

Attracting experienced and young people: An objective or a result?

An organisation is normally a complex product of many facets, all contributing to the image (and substance) of the organisation itself. None of these facets may be determinant when it is considered separately from the rest, but each can be important in creating a balanced and harmonic combination, that is, the "spirit" of the organisation. One can take economy as an example. There is no doubt that a sound economy is very important, as it provides for functional equipment and office space and for the salary of the employees. Yet, access to funding alone may not be sufficient to create a sound "spirit" in an organisation. Lengthy practices, inefficient rules, large overhead costs and also management distance from the "base" of the organisation may cancel all the positive things that can come with accessible funds. Sooner or later, an organisation that does not make good use of the money it gets, will be in trouble.

The opposite is also true, that a company may be in deep economical recession, but still have the right spirit to overcome difficulties and bring its situation back on track. Periodic threats are normal even in healthy organisations and they can also represent an incentive towards making improvements. Threats are associated with risks and there is no vital organisation today that can prosper without taking (management) risks. Threats are obviously undesirable, but when suitably managed they can bring the employees closer together, cementing their belonging to the "group" and creating the premises for winning the struggle for survival now and for a more prosperous situation in the future.

More than its instant picture, the overall dynamics of an organisation is what counts. One can be in bad shape today, but have energy enough to build on what already exists, the constructiveness to bring new positive elements forward and the imagination to harmonise one's own capabilities with boundary conditions. And, most of all, to turn positive what at a first look may seem negative. This, in the opinion of the author, represents the real strength of an organisation.

Does this have anything to do with keeping competence and attracting young people to an organisation? In the opinion of the author, it does. Young people like challenges and are likely to enjoy working in a dynamic environment. Thus, the question on what one should do to attract the interest of the experienced people and of the younger generation is probably misleading. If young (but also old) people are not interested, it is not unlikely that there is something wrong with the organisation as such – and that this is what needs to be addressed. There can be many reasons which justify the lack of interest (de-regulation, the nuclear industry not expanding, decreasing funding), and they may be valid ones, but justifications don't help solving problems. More than justifications one needs initiative, not for the specific aim of getting experienced or young people's interest, but for creating the premises for a more dynamic organisation. A living institution, perhaps imperfect but a living and dynamic one, which is willing to improve, to strengthen its position and to look for opportunities – not only at hinderences – is likely to succeed also in attracting new employees. A sound organisation should never expose personnel or equipment to any risk, but some management risks must be taken for pursuing new avenues. By taking the entire organisation along on these new avenues and by giving people new challenges and responsibilities, one will bring a wind of optimism in to the ranks – as well as new employees.

Starting a career in the nuclear sector

There is nothing wrong for a young person to start a career in the nuclear sector, as long as this step brings new challenges, enjoyment at work and future opportunities.

Challenges

As said earlier, young people normally like challenging tasks, that is what they have been preparing for in their earlier years with their studies, games or sport activities. One should make sure that they get proportioned but demanding tasks and that they get rewarded for their job – not necessarily with pay rises. They should be put to work from day zero and given responsibility almost from the same day. They may make mistakes but mistakes often represent precious lessons. The organisation must have a safety net such that errors can be captured and corrected in time, for instance through extensive internal communication, double checks and internal reviews. Capturing errors will avoid negative consequences, but also contribute to a rapid build-up of experience. The possibility should be given to young employees to extend their contacts network and to come forward with new ideas. One must make use of these ideas when they are good. Too many "this is not the way we do things", "our rules are", "our long experience shows that…" or "already in 1977 we tried to…" will take the appetite away from an elephant: they should be avoided.

Enjoying work

It is not written anywhere that work is something one must enjoy, for many it is a task that one must perform for living. Working hard and enjoy working are however not necessarily conflicting terms and it is common knowledge that when people enjoy what they do, their performance is also considerably improved. In Norway – and probably in all Scandinavian countries, – a programme called "trivsel på jobben", which in English sounds like "enjoyment at the working place", is devised to promote a better atmosphere at work. It has to do with the perception the employees have of their working place and it is a mechanism for the management to have feedback on practical things that can be improved. In addition, as part of the routines at Halden, there exists a form for institutional "conversations" taking place twice a year between the employees and their division head ("medarbeider samtaler"). This represents a confidential, free-wheel way for the employees to present their views on working relations, to give suggestions of changes that can be made, or to communicate personal expectations and perhaps dissatisfactions with one or another aspect of their job situation.

The practices just described are non-confrontational and are useful instruments for the employees to let their opinion come forward and for the management to understand if corrections need to be made, thus anticipating potential deterioration of working relations. In addition, the Norwegian quality control programme for industry and institutions imposes the existence of an internal environmental control programme, which is executed by a small group ("miljøutvalg") constituted by employee representatives and one management representative. This has mainly the task of conducting periodic reviews that the working place guarantees the safety and health of the personnel, that it satisfies the Norwegian regulation on, e.g., office space, light and air quality requirements, fire protection etc. The output is in the form of written statements on possible non-conformities as well as on possible recommendations. The latter ones are non-binding; it is up the management to decide what should be done and how. However, also in this case, the management is provided with a tool for receiving input from, and for interacting with, the employees in a rather pro-active and constructive atmosphere.

These institutional measures complement, but do not substitute the informal communications among all management and employees levels, which is believed to constitute the key for cementing the "group" and enhancing the perception that young and older people, at low and high ranks, all work for each other and for the same "cause". For young people especially, it is important to realise that they are positively assimilated and have their say within the group. In this context, but not only here, management communication skills represent a key element (managers always say their door is open all the time, the question is whether this is true). Managers must come out of their office and talk to people. Management feedback is essential for the employees, also when it is negative: for young staff members, it represents a means to strengthening their learning and their perception that their work is important. Silence and lack of feedback may induce younger staff towards isolation and uncertainty about their working relations. If such situations persists, it can become a good reason for them to start looking for a new job.

Future opportunities

The job market in Europe has experienced substantial changes in the last few years, primarily in that job mobility amongst the young generation has increased considerably. The old model of the "job for life" is fading away for a number of reasons and a more American-like attitude is now prevailing. Under the pressure of new social and economical boundary conditions, this trend is expected to continue. A modern organisation should take this into consideration when planning for the future and be prepared that willing or not willing, changes in the ranks will necessarily occur as a result of societal structural changes. To be prepared means to plan for a dynamic personnel policy and to take advantage of the positive things that come with these changes, more than accumulating frustration because "people leave".

The rate of people leaving the Halden Project (except retirements) is rather moderate, typically 6% per year. The percent is higher in the man-machine area (~10%), where there are very many good job opportunities in Norway. In the fuel/materials and reactor operation area the percentage of people leaving is low, typically 4% per year. This is certainly not because of lack of opportunities, since university graduates as well as electronic, chemical and mechanical engineers and skilled toolmakers do have attractive alternatives. The feeling of belonging to a special "group", however, is stronger in the fuel/material/reactor area at Halden, partly for the nature of the job which tends to integrate people very strongly, partly for the way it is managed, and partly because the fuel/material/reactor area is used to navigate in strong winds. This has considerably enhanced the sense of solidarity and the "can-do-it-together" attitude of the staff.

Salaries at the Halden Project are typically 5-10% lower than in industry in Norway. Nevertheless, approximately 20 to 40 applications are received on average when a job announcement is made. For a small country like Norway, this is not bad. It is not unusual that people who left earlier, re-apply for a new job position. The decision on whether or not to employ her/him can thus be based on earlier experience. Further, the applicants may return with the experience gained in their last job.

The interest shown by the young generation in start working at the Project is probably motivated by a number of things. The special character of the Project, its international contact network and other aspects have their importance. The key factor, however, remains the feeling people have that they are not wasting their time working for the Project. Nuclear may be a sector exposed to uncertainties, but often so are other industrial sectors in today's world. The employees feel that their job experience at the Project represents almost an assurance of finding new employment in other branches, should that become necessary in the future. In other words, people have confidence in their future opportunities after having invested years of their working life at Halden.

In the Project, this may be facilitated by the fact that, although the work is almost exclusively nuclear, the type of expertise is far more generic. The number of university graduates (who amount to one third of the work force) having nuclear engineering or nuclear science degrees is in fact rather small, typically only 15% of all graduates (or 5% of the total work force).

Is nuclear background always a must?

It was just noted above that the great majority of the Halden Project university graduates have a generic educational background. Most of the university graduates have a degree in mechanical or process engineering, chemistry, physics, electronics and computer science. Some of those working in the human factors sector have a degree in industrial psychology.

This simply reflects the fact that running a test reactor and associated experiments is mostly a question of sophisticated, but mainly conventional infrastructure. The nuclear energy source makes the whole thing more complex and demanding (things "cannot" fail) as it poses greater challenges to the mechanical, thermal-hydraulics and electronic engineering. Still, these challenges are mostly of a conventional nature. Only core neutronics, safeguards and radiation protection require a specific nuclear background. This educational background can be found in young Norwegian graduates today, even if Norway is not a nuclear energy country.

All Chiefs of Operation of the Halden Reactor, with the exception of one, had and have a non-nuclear educational background. Virtually all of them came from the Trondheim university, known in Norway as a good school for mechanical and plant engineering. In the last 20 years, there has been a succession of four Chiefs of Operation. After their service at Halden, one became chief of safety at the Norwegian oil company Statoil, a second one retired and the third one left for a position in the oil sector. They are all highly respected professionals, but with due respect for their skills – which is high – the reactor operation and safety have always been attended to with the same or increased attention and success.

The key element here is to make the organisation as a whole very robust, such that it is the organisation, not only individuals, that retains the knowledge. This is achieved by a number of measures, most of them inspired by common sense. These consist mainly of:

- Well organised, easily accessible documentation. If one looks for an informal internal note written at the Project, say, in 1962 about, say, the performance of this or that component during service, one can easily locate and retrieve it. The documentation archive is simple, easily accessible, unpretentious and non-computerised; it is impressive in its effectiveness.
- Knowledge is spread among many. All Halden reactor engineers and many reactor operators, for instance, know absolutely everything about their plant. In this manner, each

reactor engineer is, potentially, a future Chief of Operation. This is achieved by normal working routines which tend to involve the entire organisation in executing tasks or solving problems, and it is facilitated by the willingness of the personnel to take responsibility when it is needed (I never heard the words “This is not my job” at Halden).

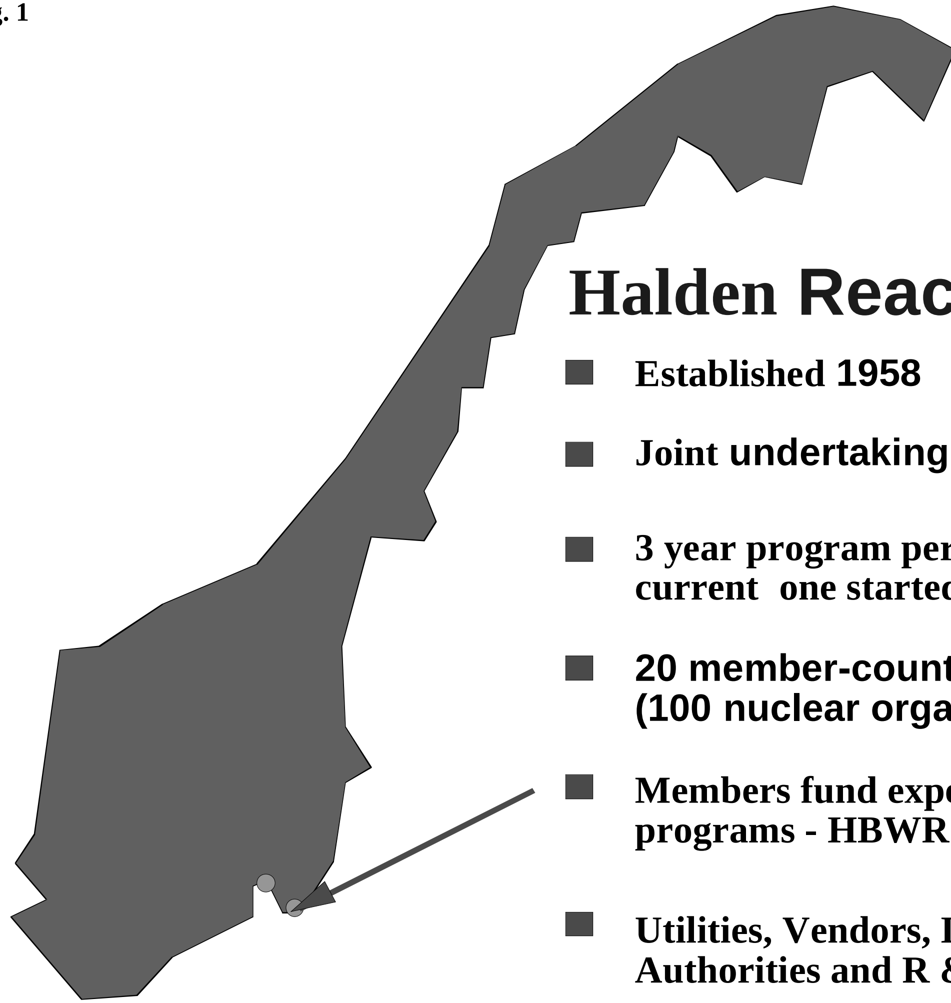
- There is always a back-up solution. Key individuals do make a difference in an organisation and it is important that their value is correctly appreciated, and when it comes to it, correctly weighted by the management. For an organisation, however, the real value is not necessarily in keeping these individuals within its ranks at any cost, but rather to have an internal dynamic able to continuously generate “indispensable” people. In doing this, the organisation becomes not only less vulnerable to unforeseen losses, but also it creates the premise for career opportunities to those willing to pursue such opportunities. In other words, behind an “indispensable” individual, there should always be the next “indispensable” one. This can be achieved – again – by distributing responsibility at an early stage, in order to naturally select those willing and capable to take the challenge. It also helps to have a reasonable degree of flexibility in job assignments, such that those who have the capability, the ambition and the strength to widen their territory of action, can do so (with due respect for their working environment).

One can conclude that a nuclear institution does not have to rely only on human resources highly specialised in the nuclear field. Good people learn quickly, especially if they are placed in the right environment, and a good mix of nuclear and conventional expertise is probably optimal. This will widen the possibilities for recruiting new staff having a broader spectrum of educational background and experience. It is important that the organisation is structured such that newcomers are quickly brought to a high level of skill and are able to take responsibility at an early stage. The organisation must be prepared for changes since some people will always be ready to leave the organisation at some point in time. If this is considered as normal dynamics and if the indispensable knowledge is in any case retained by the organisation as such, personnel changes occurring at a reasonable rate should not constitute a reason for major concern.

Concluding remark

This note represents an attempt by the author to summarise his experience in managing a mid-size R&D organisation working in the nuclear sector. It basically suggests that good interpersonal relations, stable organisation structure and simple/effective routines are probably key ingredients for a successful organisation. The author is, however, not familiar with modern and sophisticated management tools and has never read a book or attended classes on management skills. Thus, this note should be taken for what it is, i.e. a simplified account of experience that does not necessarily apply to other situations and environments.

Fig. 1



Halden Reactor Project

- Established 1958
- Joint undertaking - OECD NEA
- 3 year program periods, current one started 1/1-2000
- 20 member-countries (100 nuclear organisations)
- Members fund experimental programs - HBWR & HAMMLAB
- Utilities, Vendors, Licensing Authorities and R & D centers

Fig. 2.

In the last decade, the number of employees increased from 80 to 100 in the Man-Machine interaction area and 110 to 140 in the reactor experiment area. The administrative and support staff remained unchanged. Approximately 50% of the currently employed staff were recruited in the last 10 years (denominated "New" in the figure).

PERSONNEL CHANGES SINCE 1990

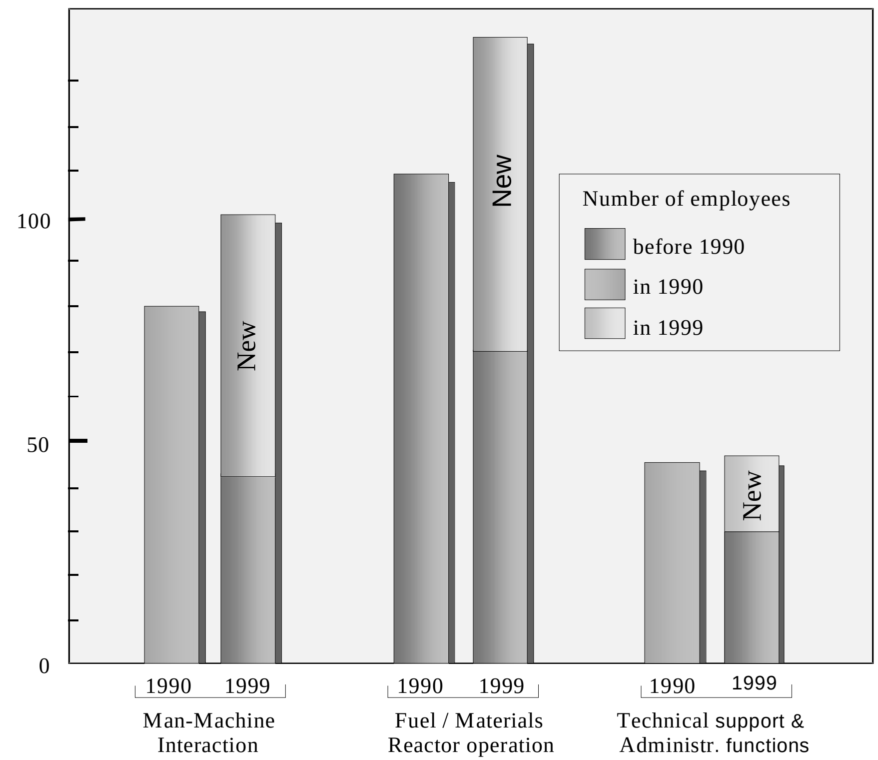


Fig. 3

Age distribution of the work force at Halden

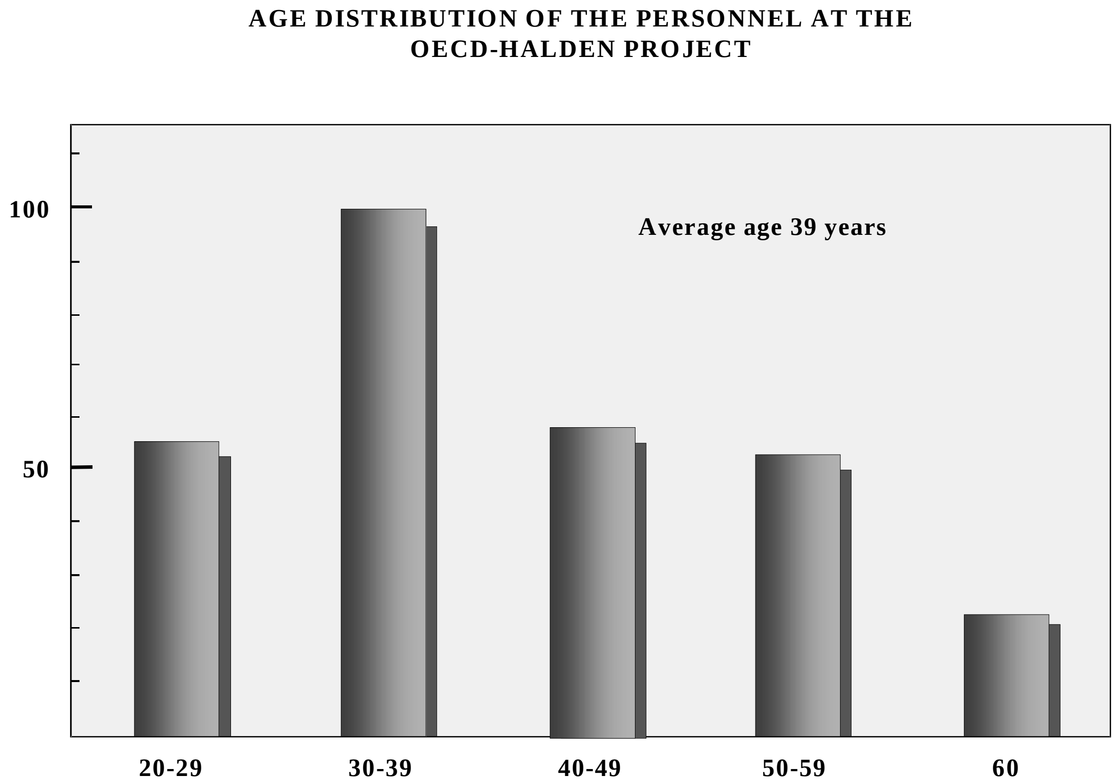


Fig. 4

The number of foreign staff with temporary assignment at Halden (“secondees”) has considerably increased in the last decade. This reflects a new function of the Halden Project in transferring technology to the younger generation, as most secondees are young scientists from Member countries

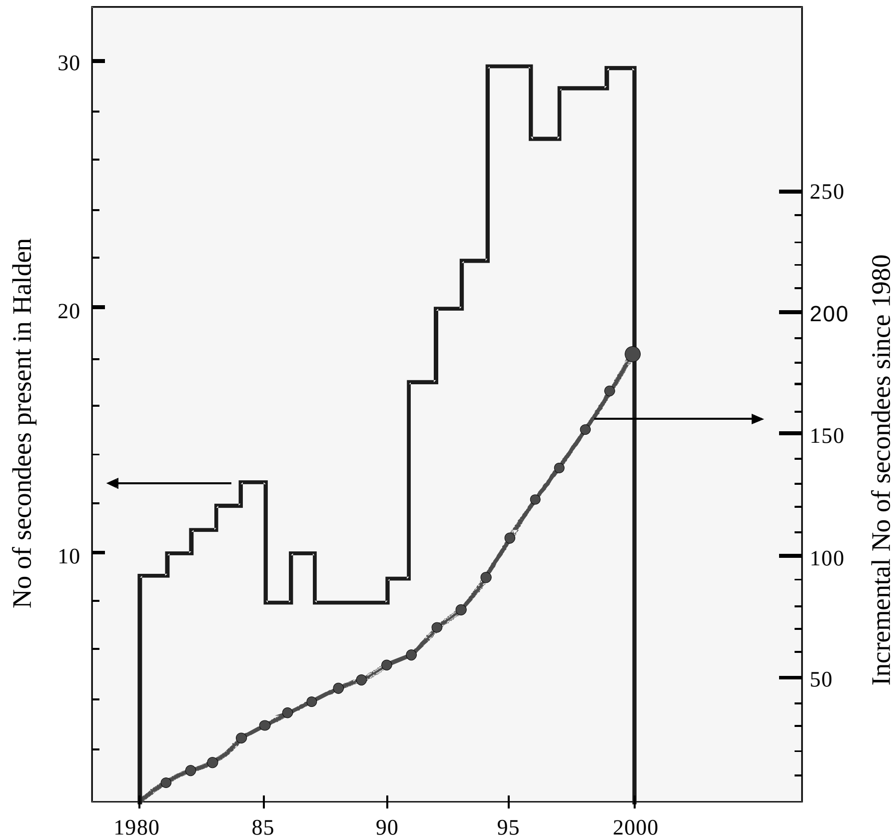
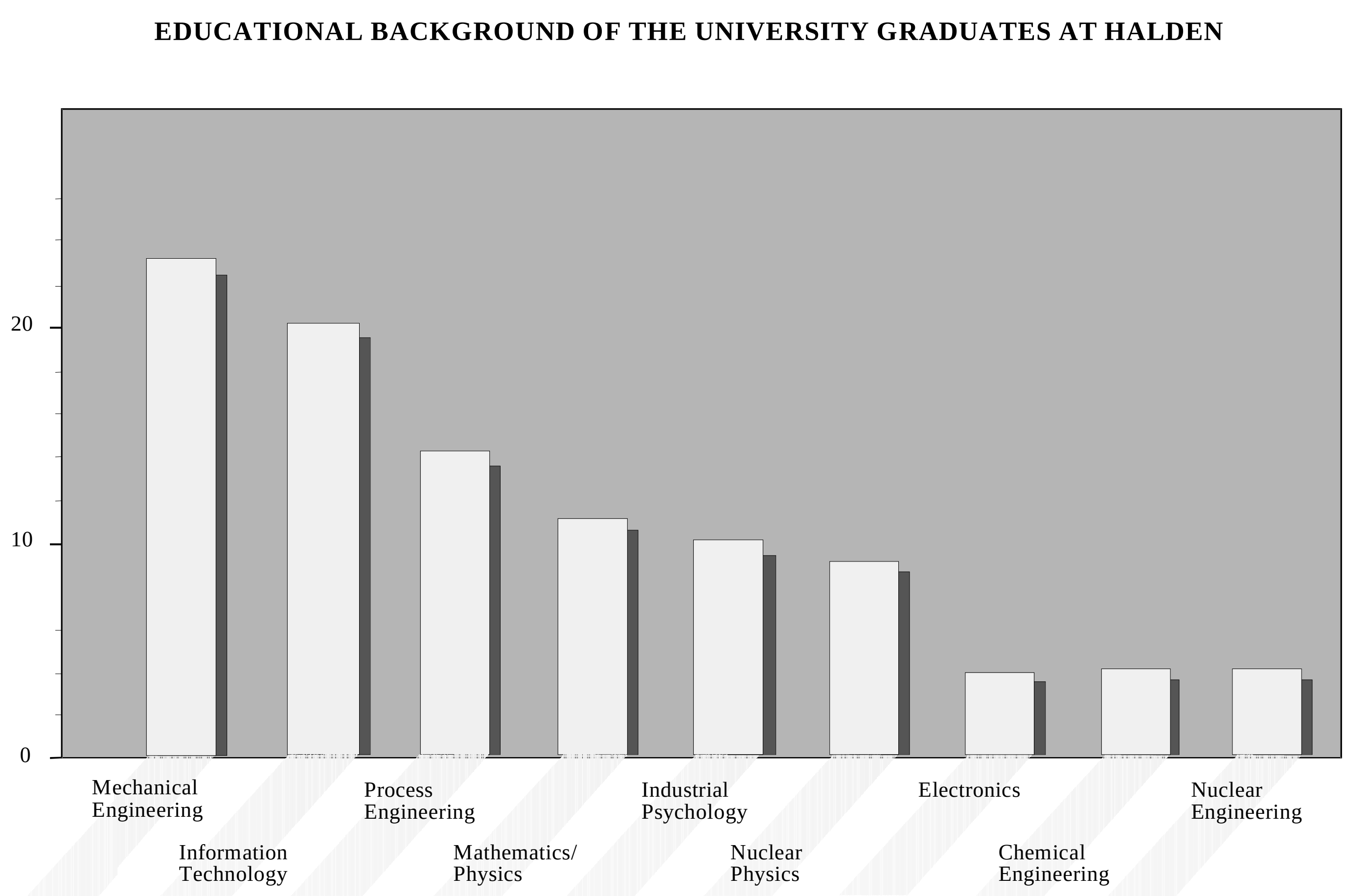


Fig. 5
This figure shows the educational background of the university graduates working at the Halden Project



HIGHLIGHTS OF SESSION B
HOW TO MAINTAIN AND CONTINUALLY DEVELOP EXISTING SAFETY CAPABILITIES

Jim Furness
Deputy Chief Inspector
Health & Safety Executive
Nuclear Installations Inspectorate, UK
St Peter's House, Room 606
Stanley Precinct, Bootle
Merseyside, L20 3LZ

The main points arising from the papers presented in Session B of the Workshop revolved around the need to provide a systematic approach to training "SAT". Many speakers agreed that the first step in this is to establish the required competency profiles for each post, considering not only present day needs but also how the required competencies might change into the future.

Having listed the required competencies, there was general agreement as to the importance of identifying the core of unique nuclear competencies which must be preserved i.e. those disciplines which do not form part of traditional engineering, physics or chemistry university courses, which it is assumed will survive without special support from the nuclear industry.

Speakers referred to the need to establish proper succession planning, having regard to the fact that in most countries, the bulk of those employed are in the 45-55 year age band. The exception to this was in Korea where the average age of those employed is around 40.

There was considerable discussion on ways of attracting entrants to the nuclear industry to meet succession needs; the use of summer and part-time jobs, allocating students interesting projects and ensuring that there was adequate job satisfaction were all mentioned. It was acknowledged that recruitment to what is perceived to be an ageing industry with little future development will be difficult, especially in the face of competition from other hi-tech industries e.g. IT.

Both for existing workers and for new entrants, training needs must be established by comparing required competencies against those already held by the individuals concerned. This process was termed a "training needs analysis". The next stage is to amalgamate individual training needs to establish programmes of site based, regional, country or country grouping training courses, exchanges, attachments, opportunities for mentoring or for distance learning etc. The role in transfer of knowledge, of co-operation with equipment vendors was mentioned, as was the value of international training courses and in particular the Frédéric Joliot/Otto Hahn summer schools. International research programmes were also discussed as a means of maintaining competence in specialist areas.

In all of this, the need to give particular support to training in the areas where the required competencies are unique to the nuclear industry was emphasised. Examples given were core neutronics, safeguards and radiation protection.

Finally, the Workshop emphasised the point that all of the above good practices are not only matters for those who operate nuclear power plants. They are of equal importance to regulators, designers, vendors, and consultants involved in the nuclear industry.

SESSION C

How to Establish Nuclear Safety Capabilities to Meet Future Challenges

Chairman: Dr. T.H. Isaacs

MAIN CONCLUSIONS OF A SEMINAR ON MANAGING TECHNICAL RESOURCES IN A CHANGING NUCLEAR INDUSTRY

P.D. Storey
Health & Safety Executive
Nuclear Safety Directorate
Room 313, St. Peter's House – Stanley Precinct
Bootle, Merseyside, UK
peter.storey@hse.gov.uk

Summary of points from I Mech E Conference
Managing Technical Resources in a Changing Nuclear Industry
(London, 29 September 1999)

UK Position

- Change to management structures and down-sizing/ out-sourcing of technical support is of considerable regulatory interest.
- Concern that changes in UK industry, if not properly controlled, could be detrimental to safety.
- New licence condition requires licensee's to substantiate changes to organisation and resources.

BNFL Magnox and AEAT

- Consolidation of technical resources into a big Technical Services Company is seen as the way forward.
- Service both nuclear and non-nuclear business and enable learning from a wide range of industries, refreshment of staff and opportunities for younger staff to develop by movement across boundaries.
- Further partnering including within a wider international context were seen as future possibilities, particularly where key facilities such as research reactors, that are in short supply, are required.

UK view from BEGL

- A base of contractor support will always be required to support the UK nuclear industry, this is not new. The industry cannot always be expected to retain key specialists in house.

View from WANO

- Competition from a deregulated electricity market is good, sharing continues, and safety has improved in deregulated industries.
- Expectations from the highest level in a company (Chief Executive) affect the behaviour of an organisation, no mixed messages.
- The safety message must get down to all members of the workforce and be practiced, it is more than words. Add on's can dilute the message, i.e. safety first but commercial a very close second.

UK view form UKAEA

- Processes are required to assess the workload and technical capability of an organisation against its future business objectives.

- The output allows shortfalls in resources, including specialist areas, to be identified and training/recruitment to be implemented.

- Clear management responsibilities and accountabilities are vital to ensure ownership and control of all activities on the licensed including those of contractors.

USA view from PECO Energy

- Utilities aim to achieve operational excellence and require both excellent human and team performance as well as excellent equipment performance.
- Organisation needs to know what safety looks like, who owns safety and who is accountable.
- Managers to be in touch, out on the plant, focus on right issues and be critical through aggressive self assessment of organisation.
- Excellent safety performance clearly linked to Operational excellence.
- Consolidation of organisations through Vendor partnering was seen to bring about benefits of technology transfer, exchange of best practice, best utilisation of skilled workforce.

View from US NRC

- Policy to adopt increased use of Risk Informed regulation made by USNRC in 1995 enables focus to be made on risk importance.

- Risk informed oversight process together with safety performance indicators allows judgement on any falling standards.
- Used safety performance of Airline and Railroad industries to show deregulation need not be incompatible with safety performance.
- “Back Fit” rule in US does not allow NRC to impose unreasonable (Cost Benefit Analysis applied) additional burden on industry.
- Future supply of specialists in nuclear technology threatened due to reduced number of nuclear specific university courses and decreasing interest of students to work in nuclear technology.
- Job market thought to be good with salaries typically near top of range in USA and Mainland Europe.

View from OECD NEA

- Long term availability of sufficient nuclear research in the right areas seen as a threat due to reducing budgets.
- International collaboration to share costs and the results of work encouraged.

CURRENT POSITIONS IN OECD MEMBER COUNTRIES ON COMPETENCE PROFILES AT PRESENT AND REQUIREMENTS FOR THE FUTURE: REVIEW OF QUESTIONNAIRE RESPONSES

J. S. Griffiths
Health & Safety Executive
Nuclear Safety Directorate
Room 217, St Peter's House
Stanley Precinct, Balliol Road
Bootle, Merseyside L20 3LZ, UK
steve.griffiths @ hse.gov.uk

G. Macsuga
Head of Centre for Emergency Responses
Hungarian Atomic Energy Authority
Nuclear Safety Inspectorate
Pf.: 676, 1539 Budapest 114, Hungary
macsug@dido.nsi.hu

Introduction

The CNRA report on Future Nuclear Regulatory Challenges identified the human element as being one of the most critical aspects of maintaining regulatory effectiveness, efficiency and quality of work. Lack of new plant in most OECD countries is having a number of effects on the Nuclear Energy industry. Job opportunities are affected which in turn has an impact on the education sector, leading to potential loss of expertise. If this trend is to continue one of the key challenges will be how to maintain corporate memory and how to ensure that the key competences required now and into the future are made available. There are no easy and simple answers as the issue is a complex mixture of interrelated social, technical and political factors. As part of the development of the workshop on assuring nuclear safety competences into the 21 St. century, the organising committee agreed to establish some baseline information which would assist in the development of potential solutions. One of these pieces of information was the detailed OECD nuclear education study, an overview of which is being presented at this workshop. In addition the aim was to obtain some general information about the trends and issues in each country. In this way it is hoped that combination of this general information with the more specific detail on individual issues would prompt discussion and facilitate potential solutions and recommendations.

Nature of the questionnaire

As a precursor to the workshop information was requested from OECD member states through CNRA. This was done in the form of a questionnaire which addressed three areas of interest. The objective was to obtain some general information to provide the context plus some specific information which if necessary would be capable of analysis. The specific areas of interest were:

Overview of current industry status in the country

- numbers of operating nuclear power units and fuel facilities;
- numbers being decommissioned;
- date of last reactor commissioned;
- fuel cycle plants in construction;
- current industry structure;
- current regulatory structure.

Manpower within the regulator and industry

- age profile of regulators and advisory bodies;
- recruitment profiles, now and into the future;
- loss rates;
- key disciplines.

Current practices from which lessons may be learnt

- training approaches;
- corporate memory;
- programmes to attract new staff;
- views on emerging trends.

Overview of survey results

A number of countries responded and a range of general and factual data provided. Some of the information was very detailed and identified methodologies and initiatives which are in place within the respective countries. In some instances these were sufficiently detailed that they have been presented as separate papers at the workshop as they provide some views on practices which may be able to be transferred to other countries.

The current status of nuclear power within the countries that responded fell into two broad groups. Firstly what can be described as the European and North American block where there has been few or no new facilities in the last 5 years and few plans to build new plant. The other group was Asia where there is expansion of nuclear energy production. This finding not surpassingly reflects the comments in the CNRA report. There was also a theme in all cases of the changing nature of the industry and how competitive pressures were affecting how the industry operated and how regulator responded. Whilst there have been no responses requested from Eastern Block countries (as they are not OECD members) the challenges they face are well known and will continue to arise as a result of the need to upgrade the level of reactor safety.

Staff loss rates

In respect of a country's ability to maintain nuclear safety competence some of the crucial factors are the numbers of staff required both by the regulator and the industry, the number recruited, the number lost and the methods adopted to ensure that no skill or competence gaps appear. The picture painted by the responses was very heavily based on the age of the nuclear industry within the country and whether there were any future plans. The European information largely showed that the regulator was staffed by people who had "grown up" with the industry. The average age of regulators tended to be in the 40s. There was also a steady trickle of retirements from all of the regulators. Loss rates of 2 to 3% per year are normal. Even based on these small loss rates the numbers of staff who will be lost over the next 5 or ten years is significant. This in it self poses problems in terms of maintaining key skills and competences. In the UK for example the loss rate over the next 5 years is about 8%, however if this is extrapolated forward for 10 years the loss rate rises to about 40% of staff. In contrast the manpower situation in the Pacific rim is more stable. Loss rates are lower and from a potentially larger pool. There is also active and regular recruitment, hence there is a steady flow into the system. This does not mean to say that there is no recruitment in Europe and America. The UK is actively recruiting because of the potential losses and the workload. There is also some targeted recruitment in other countries.

The manpower picture for the industry is much more complex as the industry structure within each country will vary, creating different interfaces. Again the Pacific rim is very active and the nuclear industry still attracts staff in terms of a career. In other countries the competitive pressures on the utilities are causing them to look for economies and operate efficiently with reduced in house manpower. These are issues described in more detail in other papers.

Recruitment practices

Recruitment practices to the regulatory bodies vary, however all countries require a university or equivalent education. A number of countries have traditionally recruited staff into the regulatory body from the utilities or related industries. They have sought some knowledge and experience of the industry as a prerequisite. This approach generally skews the age profile. There is some use of direct university entry to the regulator but again the qualification is normally a technical or scientific degree. This approach appears to be prevalent in the Pacific rim. More recently options are being examined in some countries whereby staff with a more limited nuclear industry experience are recruited. This will lead to the need to review the training programmes and approaches for the regulator.

The industry position is more varied. Recruitment is to a range of jobs requiring different levels of competence. The practice reflects the technical nature of the industry and the recruitment pool is based on those with university level education or recognised occupational or vocational training. The vocational training approach in Germany is one example of a national system across a range of industries but also seeks to ensure that nuclear power plants find skilled workers, foremen, technicians, engineers and scientists in a documented and structured framework. This forms the basis for employment and further in house controlled training is aimed at providing specialist skills and knowledge in aspects such as nuclear engineering. This approach is extended in Germany and in some other countries such as USA to formal certification and qualification of some posts in accordance with their safety relevance. Other countries make use of techniques such as the systematic approach to training or a demonstrable training record which sets out the skills required and how they have been obtained. It is clear that across the industry there is a significant requirement for on the job training which is related to the posts and that this training will also make use of national education and training systems.

Age profiles within the industry are again more difficult to determine because of the larger numbers of staff than within the regulator. Where the industry is not growing the ability to retain staff becomes more difficult. People do not enter as a career and in the future there is likely to be greater turnover of staff particularly where there may be transient discipline shortages. This is also placing pressures on existing staff. One of the challenges for industry is undoubtedly approaches to train and develop but more importantly to ensure that motivation and commitment is retain. These in themselves present very real safety challenges and are at the heart of some of the human performance aspects of safety within the industry. This emphasises some of the new challenges for the regulator as they have to ensure that they have the skills and competences to regulate this important aspect.

Competence areas identified

Examples of country practices

A number of initiatives and responses to the challenges are under development.

Most respondents have a range of in house training programmes coupled with on the job training. Where specific needs are identified this is supplemented by specialist in house training or training provided by an external body. This may range from university or higher education departments to commercial providers.

At Loviisa retirements over the next 5 to 15 years are likely to give rise to skill gaps and a need to address now how to maintain corporate memory. The objective is to maintain and enhance the expertise of their own staff by use of project work. This project is the subject of a more detailed paper at the workshop. It does however illustrate the type of initiative that is needed and how this interfaces with strategies for maintaining human capital, providing motivation and challenge in jobs and tasks. This aids in staff retention but also provides for job satisfaction. A final feature is the opportunity to involve younger engineers to ensure that skills are transferred and new ways of working developed. This approach has been extended by STUK with programmes to attract young people by shifting their recruitment profile. Further measures to be proactive with universities and colleges should also provide a useful approach in bringing the industry to the prospective employee.

SKI are in the process of an analysis of the regulatory research strategy in order to make sure that long term competence are met for the regulator and the people. This comes after work to develop a more systematic identification of competence, including post profiles. Other countries have also used this approach. The UK has recently reviewed its skills and competence needs for the future to focus their current recruitment. Whilst this has not been fully post profiled it shows the need for human resource plans which go beyond the traditional annual planning round of governments.

Groups within the industry have been formed and lobby the case. The ENS young generation network is one such group which seeks to promote the role of young people in nuclear engineering and science. This is an example of proactive cooperation across the industry and countries.

As the industry becomes more competitive within each country there is increased scope for "corporate recruitment". In this model staff would be recruited into the Energy company with limited regard for Nuclear specialisation. In this type of model it is possible that the specialist function then becomes part of a separate organisation who are contracted to provide these services. This is a significant concern with regard to retention of corporate memory, ownership of the information and maintaining the right key skills. This type of issue is emerging in the UK and is a driver for the concern over intelligent customer and the introduction of a new licence condition on organisational change. This concept was also one of the lessons from Milstone in Canada.

The human requirements for the future have been the subject of programmes of work in the Canadian nuclear industry. The strategy is based around organisational performance in terms of management requirements and a workforce plan. This is in part based on training initiatives to improve managerial capability and performance coupled with the development of succession plans around key positions. Communication of what is to be done and how forms a key part of the initiative. This work is a major 5 to 10 year organisational plan and review based on the human and technical needs at each of the nuclear operating units incorporated within the corporate business mission. This plan sees a slight increase in staff and loss rates being matched by increased recruitment. It is clear that the emphasis of this plan is to enhance managerial and leadership skills and creates a more effective business based organisation. This approach is also an area in which WANO is active with their ideas over refreshment programmes and external benchmarking of performance.

Conclusions

The picture is mixed and very dependent on the state of the industry in the particular country. A key determinant is the social, political and economic views of the place of nuclear power generation within the energy policy. Where there is support at a political level or there are clearer financial incentives then the industry can develop and has the impetuous to maintain their capabilities and competence. If the industry position is not as strong the social pressures increase so that it is not viewed as a career. Recruitment and retention and maintaining competence becomes more difficult. Furthermore there are trends to move away from the traditional engineering and science degrees towards subjects which have a "consumer vogue" and even more proven track records of employment. This in turn puts pressure on the availability of university level education at all levels. Hence if there are not well developed alternatives within a country and programmes of cooperation the very foundation of training and development is under threat.

The problems have been recognised and there are a number of initiatives in place both in regulatory bodies, training establishments and the utilities. Recognition of the problem and transfer of good practices will help. Fundamentally there has to be the underpinning infrastructure to support education and training which in itself will allow for cross fertilisation with the industry.

It is clear that the problem is international and there has to be scope for international cooperation.

Table 1. **Summary of manpower information for regulators**

Country	Average age	Loss rate short term	Loss rate 10 years	Recruitment
Belgium				
Netherlands	40			
Japan	<40	matched by recruitment	matched by recruitment	annually
Canada	40	15% per year	retirements	limited
Korea	40	nil	nil	active
Finland	45	4% of staff	12% of staff	limited
Sweden	44	8% of staff	14% of staff	nil
UK	40	8% of staff	40% of staff	active 2% per year

HIGHLIGHTS OF SESSION C
HOW TO ESTABLISH NUCLEAR SAFETY CAPABILITIES TO MEET FUTURE CHALLENGES

Thomas H. Isaacs
Director
Office of Policy, Planning and Special Studies
Lawrence Livermore National Laboratory
Livermore, California, USA
Isaacs2@llnl.gov

The main points arising from the papers presented in Session B of the Workshop revolved around the need to provide a systematic approach to training "SAT". Many speakers agreed that the first step in this is to establish the required competency profiles for each post, considering not only present day needs but also how the required competencies might change into the future.

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Speakers referred to the need to establish proper succession planning, having regard to the fact that in most countries, the bulk of those employed are in the 45-55 year age band. The exception to this was in Korea where the average age of those employed is around 40.

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Both for existing workers and for new entrants, training needs must be established by comparing required competencies against those already held by the individuals concerned. This process was termed a "training needs analysis". The next stage is to amalgamate individual training needs to establish programmes of site based, regional, country or country grouping training courses, exchanges, attachments, opportunities for mentoring or for distance learning etc. The role in transfer of knowledge, of co-operation with equipment vendors was mentioned, as was the value of international training courses and in particular the Frédéric Joliot/Otto Hahn summer schools. International research programmes were also discussed as a means of maintaining competence in specialist areas.

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LIST OF PARTICIPANTS

BELGIUM

Professor Michel Giot
Vice-Chairman of the Board of
the Mol Nuclear Research Centre
Université Catholique de Louvain
Unité TERM
Place du Levant, 2
B-1348 Louvain-la-Neuve

Phone: +32 (10) 47 22 10
(Secretary: 22 00)
Fax: +32 (10) 45 26 92
E-mail: giot@term.ucl.ac.be

CANADA

Mr. Ian M. Grant
Manager, Technical Training Group
Atomic Energy Control Board
280 Slater Street
Ottawa K1P 5S9

Phone: +1 (613) 995 2031
Fax: +1 (613) 943 0871
E-mail: grant.i@atomcon.gc.ca

FINLAND

Mr. Eero Patrakka
Manager, Development
Teollisuuden Voima Oy
FIN-27160 Olkiluoto

Phone: +358 (2) 83813300
Fax: +358 (2) 83813303
E-mail: eero.patrakka@tvo.tvo.elisa.fi

Dr. Timo Vanttola
Chief Research Scientist
VTT Energy
Nuclear Energy
Tekniikantie 4C, Espoo
P.O. Box 1604
FIN-02044 VTT

Phone: +358 (9) 456 5020
Fax: +358 (9) 456 5000
E-mail: timo.vanttola@vtt.fi

GERMANY

Dr. Gerhard Feige
Regierungsdirektor
Bundesministerium für Umwelt,
Naturschutz und Reaktorsicherheit (BMU)
Postfach 12 06 29
D-53048 Bonn

Phone: +49 (228) 305 2857
Fax: +49 (228) 305 2899
E-mail: Feige.Gerhard@BMU.de

HUNGARY

Mrs. Agota Hanti
Nuclear Power Plant Paks
P.O. Box 71
H-7031 Paks
Phone: +36 (75) 506 920
Fax: +36 (75) 506 796
E-mail: szaboag@npp.hu

Mr. István Kiss
Nuclear Power Plant Paks
P.O. Box 71
H-7031 Paks
Phone: +36 (75) 507 628
Fax: +36 (75) 508 371
E-mail: kissi@npp.hu

Mr. Géza Macsuga
Head, CERTA
Hungarian Atomic Energy Authority
Nuclear Safety Directorate
P.O.B. 676
H-1539 Budapest
Phone: +36 (1) 355 9937
+36 (1) 355 0528
Fax: +36 (1) 355 1591
E-mail: macsuga@haea.gov.hu

Prof. Zoltán Szatmáry
Director
Institute of Nuclear Techniques
Budapest Technical University
H-1521 Budapest
Phone: +36 (1) 463 2523
Fax: +36 (1) 463 1954
E-mail: szatmary@reak.bme.hu

Dr. Lajos Vöröss
Deputy Director General
Head, Nuclear Safety Directorate
Hungarian Atomic Energy Authority
Margit krt 85, Pf. 676
H-1024 Budapest
Phone: +36 (1) 355 0528
Fax: +36 (1) 355 1591
E-mail: voross@haea.gov.hu

KOREA

Dr. Manwoong Kim
Principal Researcher
Department of Engineering Research
Regulatory Research Division
Korea Institute of Nuclear Safety
19 Goosong-dong
Yusong-gu, Taejon 305-600
Phone: +82 (42) 868 0473
Fax: +82 (42) 861 9945
E-mail: mwkim@kins.re.kr

MEXICO

Mr. Guillermo S. Alcocer Gomez
Technical Consultant
Comisión Nacional de
Seguridad Nuclear y Salvaguardias
Dr. Barragán No. 779
Col. Narvarte, México 03020, D.F.
Phone: +52 (525) 590 98 53
Fax: +52 (525) 590 61 03
E-mail: cnsns1@servidor.unam.mx
Guillermo@mailcity.com

THE NETHERLANDS

Mr; Robert J. van Santen
Head, Nuclear Safety Department (KFD)
Ministry of Social Affairs and Employment (SZW)
P.O. Box 9081
2509 LV Den Haag

Phone: +31 (70) 333 5549
Fax: +31 (70) 333 4018
E-mail: rvsanten@monszw.nl

SLOVENIA

Dr. Borut Mavko
Head, Reactor Engineering Division
“Jo ef Stefan” Institute
University of Ljubljana
Jamova 39
61111 Ljubljana

Phone: +386 (61) 188 53 30
Fax: +386 (61) 161 23 35
E-mail: borut.mavko@ijs.si

SPAIN

Prof. Agustin Alonso Santos
Commissioner
Consejo de Seguridad Nuclear
Justo Dorado 11
28040 Madrid

Phone: +34 (91) 346 0335
Fax: +34 (91) 346 0378
E-mail: aas@csn.es

Mr. Manuel Rodriguez
Head, Technical Director Cabinet
Consejo de Seguridad Nuclear (CSN)
Justo Dorado, 11
28040 Madrid

Phone: +34 (91) 346 0171
Fax: +34 (91) 346 0588
E-mail: mrm@csn.es

SWEDEN

Dr. Gustaf Löwenhielm
Director, Department of Research
Swedish Nuclear Power Inspectorate (SKI)
Klarabergsviadukten 90
SE-106 58 Stockholm

Phone: +46 (8) 698 84 96
Fax: +46 (8) 66190 86
E-mail: gustaf.lowenhielm@ski.se

UNITED KINGDOM

Mr. Jim Furness
HM Deputy Chief Inspector
Nuclear Installations Inspectorate
Health & Safety Executive, Room 606
St. Peter’s House, Stanley Precinct
Balliol Road, Bootle
Merseyside L20 3LZ

Phone: +44 (151) 951 4957
Fax: +44 (151) 951 3968
E-mail: linda.colley@hse.gov.uk

Prof. Anthony J.H. Goddard
Head of Computational Physics
T.H. Huxley School
RSM Building
Imperial College of Science,
Technology and Medicine
Prince Consort Road
London SW7 2BX
Phone: +44 (171) 594 9320
Fax: +44 (171) 594 9341
E-mail: a.goddard@ic.ac.uk

Mr. J. Steve Griffiths
Health & Safety Executive
Nuclear Safety Directorate, Room 217
St Peter's House, Stanley Precinct
Balliol Road, Bootle
Merseyside L20 3LZ
Phone: +44 (151) 951 4178
Fax: +44 (151) 951 4163
E-mail: steve.griffiths@hse.gov.uk

Dr. Susan Ion
Director, Technology and Operations
British Nuclear Fuels plc
Risley, Warrington
Cheshire WA3 6AS
Phone: +44 (1925) 832 152
Fax: +44 (1925) 833 576
E-mail: seil@ bnfl.com

Mr. Peter Readle
Director, Commercial Projects
British Nuclear Fuels plc
Risley
Warrington
Cheshire WA3 6AS
Phone: +44 (1925) 832 090
Fax: +44 (1925) 834 523
E-mail: phr2@bnfl.com

Dr. David R. Weaver
MSc Course Supervisor
School of Physics and Astronomy
The University of Birmingham
Edgbaston, Birmingham B15 2TT
Phone: +44 (121) 414 4660
Fax: +44 (121) 414 4577
E-mail: d.r.weaver@bham.ac.uk

UNITED STATES OF AMERICA

Prof. Gilbert J. Brown
Nuclear Engineering Programme
University of Massachusetts-Lowell
1 University Avenue
Lowell, Massachusetts 01854
Phone: +1 (978) 934 3166
Fax: +1 (978) 934 3047
E-mail: gilbert_brown@uml.edu

Mr. Thomas H. Isaacs
Director
Office of Policy, Planning and Special Studies
Lawrence Livermore National Laboratory
7000 East Avenue, L-019
P.O. Box 808, L-19
Livermore, California 94551
Phone: +1 (925) 422 4608
Fax: +1 (925) 423 7986
E-mail: isaacs2@llnl.gov

INTERNATIONAL ATOMIC ENERGY AGENCY

Mr. Ilari Aro Training Specialist Department of Nuclear Safety International Atomic Energy Agency Wagramerstrasse 5 P.O. Box 100 A-1400 Wien Austria	Phone: Fax: E-mail:	+43 (1) 2600 22552 +43 (1) 26007 i.aro@iaea.org

OECD NUCLEAR ENERGY AGENCY

Ms. Lise Moen OECD Halden Reactor Project Institutt for Energiteknikk Postboks 173 N-1751 Halden Norway	Phone: Fax: E-mail:	+47 (69) 21 22 00 +47 (69) 21 22 01 lise.moen@hrp.no
Mr. Jacques Royen Nuclear Safety Division OECD Nuclear Energy Agency Le Seine-Saint Germain 12 Boulevard des Iles F-92130 Issy-les-Moulineaux France	Phone: Fax: E-mail:	+33 (1) 4524 1052 +34 (1) 4524 1129 (or 1110) jacques.royen@oecd.org royen@nea.fr

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