NESTet 2011

NUCLEAR EDUCATION AND TRAINING

Transactions

Prague, Czech Republic
15 -18 May 2011

ENS
EUROPEAN NUCLEAR SOCIETY

ENS CONFERENCE

organised in collaboration with:

IAEA

sponsored by:

Westinghouse

tecnatom

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ISBN 978-92-95064-12-6

These transactions contain all contributions submitted by 13 May 2011.

Monday 16 May 2011

ENEN'S CHALLENGES IN RESPONSE TO THE INDUSTRY AND REGULATORY NEEDS

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ABSTRACT

The European Nuclear Education Network (ENEN) Association is a non-profit organization established by the consortium of the EU 5th Framework Programme (FP) ENEN project in 2003. Its main objective is the preservation and further development of expertise in the nuclear fields by higher education and training. As of April 2011, the ENEN has 60 members in 18 European countries, South Africa, Russian Federation, Ukraine and Japan.
Based on the mutual recognition and adoption of the European Credit Transfer and Accumulation System (ECTS) within the EU, the ENEN has provided support to its members and European students/young professionals by organising selected Education and Training (E&T) courses in the nuclear field. The ENEN also developed a reference curriculum in nuclear engineering, consisting of a core package of courses and optional substitute courses in nuclear disciplines, to be realised in order to obtain the "European Master of Science in Nuclear Engineering (EMSNE)", the ENEN Certificate, which has been implemented from 2005. In December 2008 the European Council welcomed the existence within the EU of coordinated teaching and training leading to qualifications in the nuclear field, provided notably by the ENEN.
Since 2009 the ENEN is involved in four FP7 European Fission Training Scheme (EFTS) projects in order to establish a common certificate for professionals at European level. ENEN launched also since 2009 the EUJEP project for exchange of Master students with Japan, the ECNET 7th FP project for E&T cooperation with China in March 2011 and one with Russian Federation is to be launched in May 2011.

1. INTRODUCTION

The “European Nuclear Engineering Network” project was launched under the 5th Framework Euratom Programme in January 2002. It established the basis for conserving nuclear knowledge and expertise, created a European Higher Education Area for nuclear disciplines, and initiated the implementation of the Bologna declaration in nuclear disciplines [1]. One of the main achievements of this project was the establishment by the partners of a non-profit international organization the “European Nuclear Education Network (ENEN) Association [2].
Several studies conducted since 2000 came to the conclusions that there were indicators that future expertise in the nuclear engineering field is at risk. This situation

followed declarations and phasing out policies which lead to a significant decrease in the number of brilliant students and in some cases even closing of relevant faculties at universities. Today around 31 % of EU's electricity is produced by Nuclear Power Plants, and with lifetime extensions, growing demands for decommissioning as well as the growth of the industry world wide, the risk of a significant shortage of educated and trained personnel is becoming a constraint. This is also aggravated by the ageing and the retirement of confirmed experts.

Through the networking activities of its members and in collaboration with other regional networks and international organizations, ENEN is aiming to the preservation of skills to meet the needs of the industry, research centres and regulatory bodies for an appropriately educated staff.

2 OBJECTIVE AND STRUCTURE

The main objective of ENEN is the preservation and the further development of expertise in the nuclear field by higher education and training in response to the needs of the sector and to the concerns expressed by international organisations with respect to the availability of a sufficient number of experts in the nuclear disciplines [3].

The ENEN Association has two kinds of members. All members should have a legal status in an EU member state or a candidate country. The Effective Members, primarily academics, provide high-level scientific education in the nuclear field in combination with research work, and use selective admission criteria. The Associated Members, such as nuclear research centres, industries and regulatory bodies, have a long-term tradition of relations with effective members in the field of research, training or education and are committed to supporting the ENEN Association. As of April 2011, the ENEN Association has members in 18 European countries, consisting of 33 Effective Members and 21 Associated Members. Since 2007, the ENEN Association has concluded a Memorandum of Understanding (MoU) with partners beyond Europe for further cooperation (South Africa, Russian Federation, Ukraine, Japan, etc.)

3 MAIN ACHIEVEMENT SINCE 2003

3.1 European Master of Science in Nuclear Engineering

Supported by the 5th and 6th Framework Programme of the European Community, the ENEN Association has established and continues to monitor the equivalence of nuclear engineering education curricula at the ENEN member universities through its Teaching and Academic Affairs Working Group. As a result, the ENEN developed the European Master of Science in Nuclear Engineering. A reference curriculum, consisting of a core package of courses and optional substitute courses in nuclear disciplines, has been designed and mutually recognized by the ENEN members. To advertise and promote this realization, ENEN has established the qualification of European Master of Science in Nuclear Engineering (EMSNE).

3.2 International Exchange and Advanced E&T Courses

The equivalence of nuclear engineering curricula relies on the mutual recognition of courses among the ENEN member universities. ENEN therefore also has the task of promoting student and faculty exchanges by encouraging and supporting the organization of international exchange courses at Master level, advanced courses at PhD level as well as training courses for young professionals.

A typical example is the Eugene Wigner course, a three-week course on nuclear reactor physics including lectures and practical exercises at three different reactors, which has been organized five times since 2003 by a group of universities and research centres in central Europe, addressing nuclear engineers and young professionals. Joint courses have also been organised on Neutronics for LWRs, Principles of Operation of Nuclear Reactors, and Dismantling Experience of Nuclear Facilities. Advanced courses at PhD level have been organized by ENEN in the framework of the Integrated Project EUROTRANS (http://www.enen-assoc.org/en/activities/for-universities/eurotrans.html). Many international training seminars addressing students and professionals have been organised on a regular basis since 2003 in France, Germany, Romania, Finland, etc.

3.3 FP6 ENEN II and NEPTUNO Projects

The implementation of the EMSNE concept was achieved under NEPTUNO FP6 project. The project developed ENEN activities related to education in Nuclear Engineering and its extension to include training courses for professionals and knowledge management by the establishment of a database on academic and training courses.

The ENEN-II Coordination Action consolidates and expands the achievements of the ENEN and the NEPTUNO projects attained by the European Nuclear Education Network Association in respectively the 5^{th} and 6^{th} Framework Programme of the European Commission. The ENEN-II project activities have been mainly structured around the five Working Areas (WA) of the ENEN Association in close collaboration with selected consortium partners. The objective of the ENEN-II project was to develop the ENEN Association in a sustainable way in the areas of nuclear engineering, radiation protection and radwaste management, including underground disposal. The current developments in the 7^{th} Framework show that this has partially been achieved. Indeed, the interaction between the different communities, engineering, radiation protection and waste management, has been considerably strengthened. The ENEN Association experience has been exploited to the benefit of the other communities in the development of their networks and the definition of their education curricula and training programs. Although the training projects ENEN-III, PETRUS-II and ENETRAP-II, now running under the 7^{th} Framework Program, are distinct activities, they have been prepared in mutual consultation by the three communities. The ENEN Association is a partner in the three consortia, assuming a pivotal role in the coordination and streamlining of education and training activities in the European Union.

3.4 **Nuclear European Fission Training Scheme** - EFTS

The ENEN Association is involved in four projects for European Fission Training Schemes (EFTS) under the 7^{th} FP of the European Commission, i.e. ENEN III on nuclear engineering, PETRUS II on geological disposal and underground storage of radioactive waste [4], ENETRAP II on radiation protection [5] and TRASNUSAFE on nuclear safety [6].

The ENEN III project covers the structuring, organization, coordination and implementation of training schemes in cooperation with local, national and international training organizations, to provide training courses and sessions at the required level to professionals in nuclear organizations or their contractors and subcontractors. The training schemes provide a portfolio of courses, training sessions, seminars and workshops, offered to the professionals for continuous learning, for updating their knowledge and developing their skills to maintain their performance at the current state-of-the-practice and to anticipate on the implementation of new scientific and technological developments. The training schemes allow the individual professional to acquire a profile of skills and expertise, which will be documented in his "Passport of Competences". The purpose and essence of such passport is its recognition within the EU (and possibly abroad) by the whole nuclear sector, thereby providing mobility to the individual looking for employment and providing an EU wide recruitment basis for employers in the nuclear sector. Such EU-wide recognition is subject to qualification and validation of the education and training components of the EFTS according to a set of commonly agreed criteria.

Training schemes in the following four generic types will be developed in the project:

- Type A) Basic training in selected nuclear topics for non-nuclear engineers and professionals in the nuclear industry.
- Type B) Basic training in selected nuclear topics for personnel of contractors and subcontractors of nuclear facilities
- Type C) Technical training for the design and construction challenges of Generation III Nuclear Power Plants
- Type D) Technical training on the concepts and design of GEN IV nuclear reactors

3.5. International Cooperation

The ENEN Association is intricately involved in several activities on nuclear education and training in the European Union.

In the framework of the Sustainable Nuclear Energy Technology Platform (SNE-TP) launched in 2007 with the aim of coordinating Research, Development, Demonstration and Deployment (RDD&D) activities in the field of nuclear fission energy, the ENEN co-chairs with the industry the Working Group on Education, Training and Knowledge Management (ETKM). The objective is to make proposals to the SNE-TP Governing Board on a future framework of nuclear education, training and knowledge management at European level and implement it in a sustainable manner. From this involvement and by its support the ENEN expects closer contacts and interactions with major industrial partners.

The ENEN Association continues to be involved in several technical meetings, consultants' meetings, workshops and conferences related to education, training and knowledge management organized by the International Atomic Energy Agency (IAEA). The ENEN Association exchanges information and participates on a regular basis to meetings of the Asian Network for Education in Nuclear Technology which has been operated by the IAEA. Asian network representatives are invited to the meetings of the ENEN Association.

4. FURTHER CHALLENGES

The ENEN Association has developed a knowledge and human network of European high-level education and training in nuclear-related subjects. together with relevant academic and industrial entities and international organizations. In the framework of the ENEN Association major nuclear education, research and some training institutions in Europe are working and acting together through education and training for the renewal of competencies across the nuclear energy life cycle (design, build, operate, decommission and dispose).
The Network contributed to fulfilling the needs of young professionals, academic entities and end-users. Through the ENEN curricula and training packages have been adjusted and the qualifications of young professionals have been enhanced, thereby improving their employment and career opportunities. Its further challenges are:

- Expand activities from the academic and research environment into the industrial and regulatory organisations and attract their membership;
- Define, harmonise and promote international mutual recognition of professional training for key functions in nuclear industries, regulatory bodies and nuclear technology applications;
- Expand into nuclear disciplines outside nuclear engineering such as radiochemistry, nuclear medicine;
- Continue to support and strengthen cooperation with other international and regional networks.

ENEN Association's members include today major universities in the EU27 involved in the education of nuclear disciplines at masters and PhD levels as well as leading research centres. Universities from worldwide, such as Russia, South Africa and Japan decided to join its activities through the establishment of a Memorandum of Understanding and new collaborations will be established in the near future with third countries such as China. Still, the future sustainability of ENEN will rely on a more significant involvement of the "future employers", the nuclear industry and regulatory bodies.
In several FP7 projects, ENEN III, ENETRAP II, PETRUS II, TRASNUSAFE, etc. the ENEN Association will be working with major industry and regulatory bodies. More synergy will be established through the activities of the ETKM working group of SNE-TP, co-chaired by industry and ENEN and its interaction with the two other working groups. For ENEN this will constitute a great opportunity to expand its activities from the academic and research environment to the industrial and regulatory organizations and to attract their membership.

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NUCLEAR EDUCATION AND TRAINING: ASSURING A COMPETENT WORKFORCE

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ABSTRACT

Over the years the NEA has been instrumental in raising awareness on issues related to education and training (E&T) in nuclear science and technology. Ten years ago the OECD/NEA report 'Nuclear Education and Training: Cause for Concern?' [Ref. 1] highlighted that core competencies in nuclear technology were suffering a significant decline, becoming increasingly difficult to sustain. The study acted as a wake-up call, urging prompt and decisive actions by governments and other stakeholders to avert the risk of irreversible consequences. Combined with more recent studies and activities subsequently undertaken by OECD/NEA [Ref. 2&3] and following a policy debate on 'Nuclear Research' [Ref. 4], a statement on the need for qualified human resources in the nuclear field was unanimously adopted by the NEA Steering Committee [Ref. 5], underlying the prime responsibilities of governments.

After 10 years, awareness has generally grown on the gravity and urgency of the issue, triggering, in some cases, significant initiatives. However, in a much altered context of growing nuclear reactor fleets, concerns still prevail regarding the availability of sufficient, skilled manpower and the adequacy of infrastructures. Strains in the human resources capacity still remain high and any potential increase in use of nuclear power might be hampered by a dearth of qualified personnel.

The current NEA project has thus been undertaken to revise and update the 2000 OECD/NEA publication [Ref. 1]. The study provides a qualitative characterisation of human resource needs, distinguishing among nuclear professionals, technical staff and crafts: categories which require different types and degrees of E&T. Instruments to address such needs, already available, underway or planned are appraised. An assessment on the current and future uses of nuclear research facilities for E&T purposes was also undertaken, based on the factual foundation of data gathered through quantitative surveys. The outcomes will be presented.

In parallel to these reviews, which address more specifically the training of nuclear professionals, the study investigates needs related to the larger part of the nuclear workforce, by mapping skills and competencies of different types of workers, encompassing functional and behavioural skills, training requirements and standards. By considering examples of job profile characterisation across countries collectively agreed as good practice, commonalities are drawn to enable the development of internationally benchmarked training standards, hence facilitating the establishment of a competent workforce, its mobility and progression and providing guidance to 'new–comers'.

By capturing common education, training and knowledge across the globe, it is possible to develop an **international taxonomy**: a system for classifying job roles and competences of the diverse workforces serving NPPs. This has the potential to be a powerful tool for workforce planning.

1. Introduction

Education, training and knowledge management in nuclear science and technology remain very topical issues with the international community. Ten years ago the OECD/NEA report 'Nuclear Education and Training: Cause for Concern?' [Ref. 1] flagged issues regarding the availability of sufficient, skilled manpower and served, at the time, as a strong wake-up call to governments in many countries. Based on comprehensive surveys, it highlighted how competencies in core nuclear technologies were becoming increasingly difficult to sustain, with retirement rates of the nuclear workforce on the increase. In order to address the challenges of revitalising nuclear education, the report made a number of recommendations calling for urgent intervention by all stakeholders: governments, universities, industry and research institutes. The follow-on OECD/ NEA report 'Nuclear Competence Building' issued in 2004 considered progress against the recommendations drawn in the earlier study, addressing the question of infrastructure as a whole. Whilst increased awareness on the gravity of the issue was reported, the study manifested persisting problems with nuclear E&T and related research infrastructure, largely linked to the long time scales and requisite specialised competence and exacerbated by retrenchments which followed the increased liberalisation of electricity markets.

In 2007, a policy statement unanimously adopted by NEA member country representatives, reiterated the need for qualified human resources in the nuclear field, reflecting the difficulties still experienced by institutions in HR development.

Concerns over nuclear E&T adequacy still prevail. Recent years have seen changes in the political and public approach to nuclear generation, with an increasing recognition of the potential contribution of nuclear power to the low-carbon energy generation needed for a global development. By the end of the decade this shift in attitude had begun to translate into policies and new build projects, and the industry appeared to be poised towards an incipient renaissance, with positive projections of growth forecasted by authoritative sources [Refs. 6, 7]. Profound reflection and some potential slowdown from this trend have been triggered by the recent tragedy in Japan, where the double natural catastrophe derived by a seismic event of unprecedented intensity and a powerful tsunami that resulted from this, hit the North-Eastern coast of the country and caused a serious accident in the nuclear power plant of Fukushima. The new status of things emerging from this is likely to curb projections for potential nuclear expansion. Furthermore, as experienced in the past, it may act as a deterrent mechanism in investments on nuclear education and training, which would jeopardise the preservation and development of related programmes and tools as well as the interest of young professionals towards the industry.

To avert this threat and maintain the stock of a skilled and competent workforce and a flow of new recruits which is sustainable in the long term and adequate to offset the attrition and impending retirement of ageing workforce, significant intervention will still be required. In any foreseeable scenario, the demand for nuclear skills will be important, not least to resource central areas such as safety, decommissioning and waste disposal. The nuclear industry is characterized by high overall skill levels, in both operations and management, reflecting the complexity of the technology and the high degree of safety regulation. Simplistically, a broad classification of nuclear manpower can be drawn, through a threefold categorization: a smaller group of high level professionals with a specialised background in nuclear subjects (e.g. nuclear engineering, radiochemistry, radiation protection, etc.); a greater number of technical workers with an adequate background in specific areas (e.g. mechanical, electrical, civil engineering, etc.) and some general knowledge of the technical and organisational nuclear environment; and a wider category of craft workers who are not required to hold high nuclear- specific knowledge but need to have acquired a degree of nuclear awareness. This is often visualised through the 'competency pyramid' (see Figure 1).

At the top of the pyramid, for the smaller group of high level professionals, the competency acquisition route is fundamentally through academic degrees of education, with in-depth knowledge based on underlying principles. Moving towards the base of the pyramid, competency development shifts to training, focused on a particular job, task or set of tasks.
Whilst the nature and depth of specific competencies vary with the job, along with the degree of nuclear knowledge and therefore the education and training required, safe behaviours are always regarded as critical overarching skills, throughout all of the above categories, as safety is a pre-eminent concern in the nuclear industry. In this respect, management and leadership skills are required which will generate and maintain an appropriately robust safety culture. In any case, different E&T needs are to be considered: for skilled engineers, professors in nuclear engineering and competent trainers - required to achieve the large processes of nuclearisation; and, just as important, for the large demand of craft and technical levels. In the US, industry workforce surveys indicate that there is a growing and persistent need for new technicians to enter the industry, and that, in fact, this dearth in the trades and crafts constitutes the greatest near-term US workforce need. This latter group needs to undergo fundamental training for nuclearisation, whilst the highly educated professionals need long periods of specialised education and experience. It is the efficient delivery of the two learning strands, training and education, which is at the heart of a steady flow of competent workers to maintain and deploy nuclear programmes robustly anchored on strong safety principles as well as good science and engineering.

The present study "Nuclear Education and Training: Assuring a Competent Workforce" discussed in this paper has been recently initiated under the auspices of the Committee for Technical and Economic Studies on Nuclear Energy Development and the Fuel Cycle of OECD/NEA and conducted by an ad-hoc expert group established for this purpose in October 2009. This study has looked at the evolution and present status of programmes and instruments for human resource development (HRD) throughout the pyramid, but particularly for the provision of the specialist nuclear education at the top, through the appraisal of initiatives that have been undertaken over the last ten years by the various actors in the international scene, as well as through a parallel survey on the use of research facilities for education and training (discussed in Section 2). Simultaneously, members of the expert group have devoted their concerted effort to the development of a job taxonomy consisting in mapping-out and typifying nuclear job profiles selected amongst those considered of greater safety significance or strategic importance (this is discussed in Section 3). By looking at examples of commonalities and approaches collectively accepted as good practice across countries an overall view of competencies, qualifications and behaviours have been identified, which are essential for personnel working in a nuclear organisation.

2. Nuclear Education & Facilities

2.1 Education and training – an outlook of progress over the last decade

Several years after the OECD/NEA report [Ref. 1], and in part in response to the situation of the crisis it highlighted, a significant number of actions have been promoted by private and international organisations, academic institutions and, to some extent, by governments. Reports provided by the country delegates of the expert group show that stakeholders have acted, but a regime of sustainable HR supply is yet to be achieved. There is evidence that progress has been accomplished in addressing certain concerns. For instance, in the last few years, the industry has acted vigorously, sometime in conjunction with other parties, and major industrial players have succeeded ramping-up their recruitment rates worldwide. This has been the case for AREVA that in the last 5 years has engaged over 40,000 new recruits (although half of these were to replace people leaving) and changed its internal organisation to favour a rapid learning process for these young engineers. Industry and universities are working well together and multilateral networks have been growing at national[1] and regional[2]

[1] Amongst others: UNENE in Canada, BNEN in Belgium, the Global Human Resources Development Initiative in Japan, FINNEN in Finland.

levels. However, the industry alone has limited abilities to change the educational system, as this is ultimately set by governments. In many countries governments have undertaken manpower assessments (e.g. Japan, France the UK, Finland, the US etc.), the results of which have, in a few cases, triggered government actions to address gaps. Noteworthy, of mention, are the cases of the United States, France and the United Kingdom. In 2006, in the United States, after a critical period of severe decline caused by the withdrawal of funds in the nuclear sector, substantial federal grants have been increasingly re-allocated in particular over the last 3-4 years. Since then, the stable involvement shown by federal government and legislators with regulators and universities, by means of funding and strong relation-based interactions, has proved to be crucially important in attracting growing numbers of students[3]. In the United Kingdom, the issue of the White Paper in 2007 [Ref. 8] has resulted, inter alia, in the creation of the Office for Nuclear Development and the roll-out of the regulatory process for new build; developments which have also provided a framework for an integrated HR planning process to emerge. Cogent Sector Skills Council was established to facilitate a demand-led link between government, industry and E&T providers, covering all aspects of nuclear workforce planning, with the direct involvement of regulators. In France, where the robust nuclear education system, long-established nationwide, has continued to be promoted in support of a strong nuclear programme, the government has set up in 2008 the CFEN[4], a new council. This was conceived to provide an interface between government, industrial actors, academic and public institutions, coordinating their efforts to enable a significant expansion of the educational offer.

Aside from these and a few other sporadic examples, however, in most cases, governments appear to have maintained the status quo, whereas firmer actions would be needed, with systematic approaches towards planning for nuclear HRD.

2.2 Analysis of the use of research facilities for E&T

To instil safety culture, in the preparation of nuclear workforce, hands-on experience is generally considered paramount. It is fundamental that trainees are exposed to the actual nuclear environment that can be reproduced in Research Reactors (RRs) and other nuclear facilities. Although the role of simulators in training is becoming increasingly widespread, the general view remains that their use, whilst unique for specific purposes (such as the reproduction of transients), is still to be considered complementary to specific training in nuclear experimental facilities. No comprehensive quantitative data on the availability and rate of use of research facilities for E&T has been reported to date. Hence, within the framework of this study, building on a recent activity developed within the EU Sustainable Nuclear Energy Technology Platform [Ref. 9], a survey was undertaken, covering RRs (including critical assemblies) and Thermal Hydraulic (TH) loops in OECD countries. Some of the outcomes of the survey are presented below. In general, the data gathered suggest that the use of RRs and THs for practical educational training appears rather limited. For instance in countries within EU 27+, roughly one half of the research reactors (28 out of 60) are used for education at MSc/BSc levels, with only a few being dedicated to civilian training. Even where facilities are well utilised for E&T, as in Canada, these are far from being exploited to their full potential. Notably the reactor at the Royal Military College of Canada is already widely used for E&T; yet an increase from 200 to 300 students per year is considered feasible. Similarly in the United States, research reactors are generally in fairly good shape, with recent upgrades made possible through the support of the federal government, and although they are reported to be used, to some extent, in educational programmes, it is still fair to say that there is an opportunity for greater utilisation of most such facilities. It is also noted that PhD and MSc theses conducted in RRs are rather infrequent. Although reliable data on the use of TH facilities for E&T are difficult to collect, due to their vast number and

[2] E.g. ANENT (Asian Network for Education in Nuclear Technology) and ENEN (European Nuclear Engineering Network)

[3] Varying, over the last two decades, from 1 800 to 600, and now back to 3 800

[4] "Conseil des formations pour l'énergie nucléaire"

wide variety, the results of the survey clearly suggest similar outcomes to those described for RRs. On the whole, the survey has shown that there is a substantial potential for an increase in the number of students that could be accommodated[5]. Several factors may influence this limited use and some of these are discussed below. Running lab sessions is only possible on small research facilities, as bigger facilities are too expensive or inappropriate for teaching purposes. Although universities are committed to offer lab sessions to students, in general, education does not figure strongly in the mission and purposes of research centres. Running experimental facilities at universities has become very difficult due to the elevated costs, not least those necessary for the enforcement of more stringent safety and security regulations. The number of students enrolled in nuclear engineering is still contained and the demand is therefore limited.

Warnings have been raised [Ref. 10, 11] over the fact that many expensive and unique facilities are due to close over the next few years. Whilst TH facilities are not so susceptible to ageing and are more easily constructed, with new ones regularly built, consideration should be given to replacing old RRs with new ones as well as the need for a new generation of small RRs at universities and the financial support required for associated operating costs, including staff.

Extending the use of RRs to countries not owning any such facilities could be envisaged through novel ways, (an example is the recent collaborative experience between North Carolina State University in the US and the Department of Nuclear Engineering at Jordan University of Science & Technology testifies). In general, building partnerships should always be encouraged. This could foster the greater utilisation of existing structures for E&T, for instance by sponsoring student internships at industrial facilities amenable for this purpose, or favouring hands-on training of reactor operators, e.g. at university-run RRs.

3. Workforce Development: A Blueprint for the Future

Ensuring a competent workforce is paramount in instilling confidence in a safety critical industry. In the nuclear industry the level of safety culture required is second to none; and those closest to safety are employees working in or for a Nuclear Power Plant (NPP).

Governments, representing national consensus, use regulators to ensure utility companies are licensed to operate NPPs safely and that vendors (of nuclear technology) design and build NPPs safely. Both utilities and vendors in turn require independent verification of standards of competence and accredited provision of training. This is required not only for their own workforces but also for those in the supply chain to whom they delegate products and services, and for whose competence they are ultimately held responsible. In this complex market of joint and several liability, frameworks that independently and systematically assure safety culture and support competence can add significant value.

With an increasing tendency to a globalised supply chain serving NPP build (B), operation (O) and decommissioning (D), it is timely to evaluate the potential of consolidating good national practice for the international benefit of an industry whose influence respects regulatory borders but whose reach extends beyond; it is timely, therefore, for a blueprint for workforce development of the future.

NPPs are based on a common nuclear science and general engineering principles applied in a variety of designs. Although specific NPP designs are protected by copyright, there have been many international licensing agreements that have resulted in the sharing of design data around the world; this is an example that workforce development can draw from. However, diversity in regulatory practice and approaches to the supply, demand and accreditation of education and skills means that there are, to date, no nationally accredited

[5] At least by 40 % in RRs and possibly more if dedicated technicians and supervisors were increased accordingly and by a factor of 3 in TH facilities.

and internationally recognised frameworks for competent workforce development. This is not to say that competence frameworks do not exist; rather, that there is a broad resource of accredited good practice that can be built into a coherent and comprehensive framework that adds value through international co-operation.

By capturing common education, training and knowledge across the globe, this paper will demonstrate that it is possible to develop an **international taxonomy**: a system for classifying job roles and competences of the diverse workforces serving NPPs. This has the potential to be a powerful tool for workforce planning that could lead to further developments in:

- workforce mobility across all occupational levels
- a robust basis for international labour market research, scenario planning and HR observatories
- international comparability and interoperability of standards, training and qualifications
- international intra-company transfers
- ‘passports’ for training and experience
- voluntary licences to practice that underpin regulatory compliance and supply chain competence assurance
- the safe and secure adoption of nuclear technology by developing countries.

In this paper we will present our work that has been undertaken with a broad network of national and international organisations, and which has been peer-reviewed by international experts. The key approach has been to harmonise existing intelligence and good practice into an illustrative set of job roles (and associated competencies) structured into taxonomic families.

The methodology has been to work ‘down’ a taxonomic hierarchy of: NPP sector, function, job role, occupational level, competence, standards, education and training. The roles chosen for illustration are deemed as critical to the three sectors of the NPP lifecycle – Build (B), Operation (O), and Decommissioning (D). The NPP sectors and functions are as follows:

- NPP-B /Design, Supply, Construction, Commission
- NPP-O /Operation, Maintenance, Waste Management, Safety
- NPP-D /Decommissioning Operations, Maintenance, Waste Management, Safety & Environment.

Within each of the functions (B, O or D) there are many job roles with ostensible nuclear and non-nuclear activities, yet all reside within a nuclear context. The extent to which nuclear-specific workforce development is required will depend on the proximity of the context to the nuclear island of a NPP. Consequently a wide range in the depth and breadth of workforce development is in scope. This includes the full spectrum of occupational levels from professional and technical to craft. **The taxonomy focuses on the degree to which nuclearisation of an occupation is required and offers a methodology for defining occupational competency, and for recognising fit-for-purpose qualifications and training.** Of highest priority is the embedding of safety culture in all contexts.

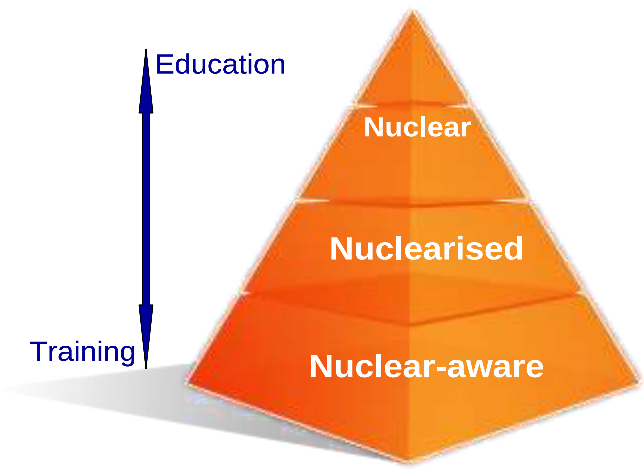
The figure below illustrates a competency pyramid drawn from the taxonomy. This represents the degree to which workforces require nuclearisation. The top of the pyramid represents the specialist nuclear educated and experienced occupations working in NPPs. The middle section represents occupations, such as mechanical engineers, that may be employed on NNP sites. These roles do not require nuclear specialism as an entry criterion but they do require significant nuclearisation for competence in a direct nuclear context. Such occupations eventually develop significant experience in the industry. The bottom of the pyramid represents the large workforces that may be transient on a nuclear site or may be providing products and services off-site to a NPP but to nuclear specifications. Examples are supply chain occupations in construction, engineering maintenance and manufacture. These workforces require awareness training (at least) and degrees of suitable experience.

In conclusion, the **international co-operation** that we have drawn together illustrates:

- **the feasiblity of a coherent and comprehensive taxonomy for nuclear job roles and competences**
- **that an international taxonomic system can add value through a common language of competence in a nuclear context**
- **that education, training and experience can be recognised co-terminously at international and national levels**
- **that the system has the potential to further the ambitions of the nuclear industry in safety, mobility, HR planning, and knowledge management.**

The detailed findings and structures of the taxonomy research will be presented.

Figure 1 – the Pyramid of Competency



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Sustainable People Development
How to ride the Waves of Critical Professions?

by Erich R. Unkrig, AREVA NP GmbH

In order to ensure sustainable business development and sustainable business success, enterprises must know what knowhow and what capabilities are required to achieve this. In this context AREVA ask themselves what positions or functions must be considered "critical" in this connection.

Due to this, a common definition was developed on a European level as a first step for what is understood by AREVA as being "critical":

- Strategically important occupational fields in which AREVA must ensure sustainable knowledge and experience
- Occupational images which are difficult to recruit on the labour market
- Occupational images which are difficult to be qualified internally
- Occupational fields with a significant quantitative development
- Occupational fields which are facing a significant (further) development of skills

On behalf of the senior management the German project "Critical Job Observatory" was implemented in the year 2010. In order to ensure the consistent use of the definitions, "face to face interviews" were implemented. These talks were conducted exclusively by People Development Germany – with the help of Technical Support to ensure the data quality by validating the technical statements about criticality.

To achieve the commitment on all management levels, the interviews were conducted top-down. In the first interview rounds the critical jobs were identified with the BU Heads of the Business Units New Builds, Installed Base, Products & Technology and Fuel, with the Division Heads from E&P and the Direct Reports to the Executive Management in the corporate sector within their respective business areas using the aforementioned criteria. In addition the criticality of the critical jobs was determined with three questions:

- Influence on the business success
- Probability of job vacancy in relation to the succession situation
- Number of knowhow carriers in the GmbH including subsidiaries

To obtain more detailed information about the identified critical job, references for further talks were determined. The following information was gathered in these analysis talks:

- Main objective of the critical job
- Topics of the task
- Knowhow/capabilities/skills/training level
- Job family

Evaluation and assessment of criticality at a glance

All of the 286 jobs were classified as critical because they require knowhow which is of strategic importance to AREVA and losing it could result in a competitive disadvantage. In addition to this classification as critical further criteria were specified for all critical jobs which comply with the aforementioned definition of critical:

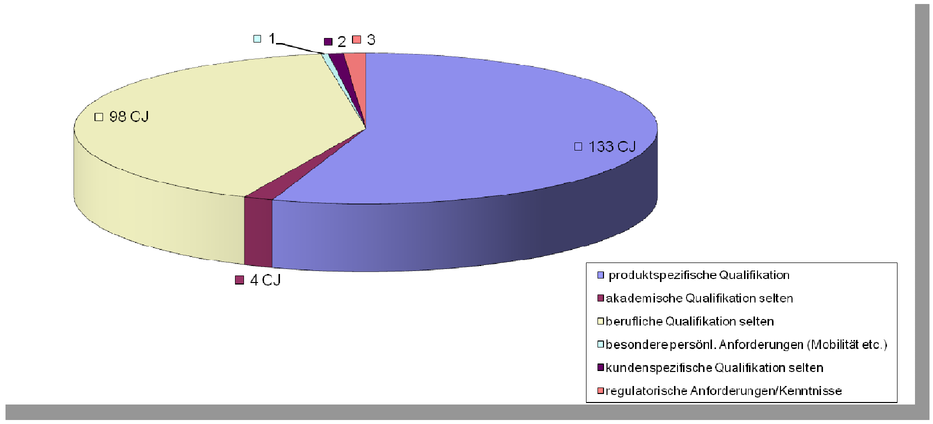

Figure 1: 84.27% of the CJs are difficult to be filled via external recruiting

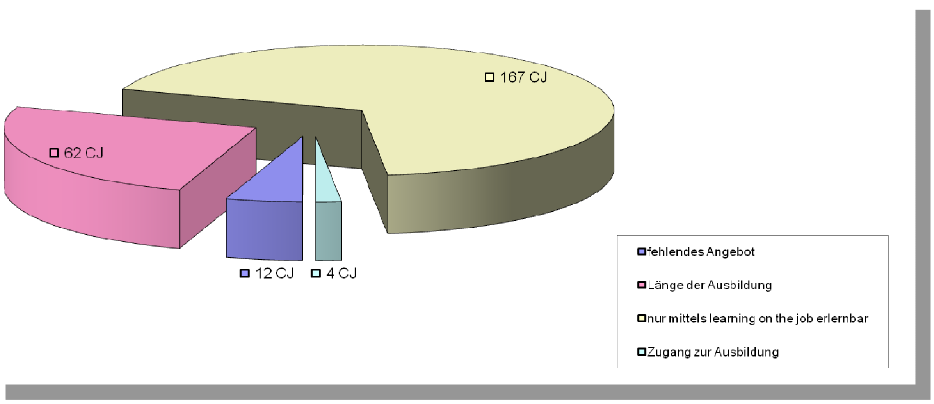

Figure 2: 85.66% of the CJs can only be filled via an intensive internal qualification/experience

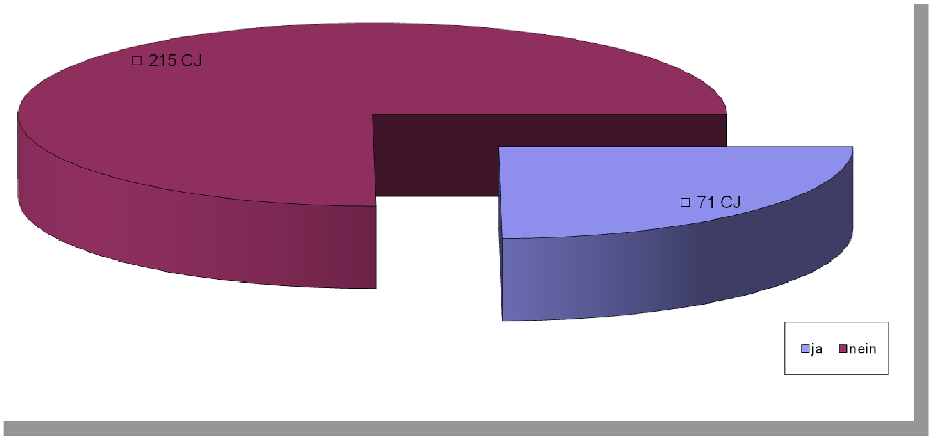

Figure 3: 24.83% of the CJs are critical because they are facing a quantitative increase

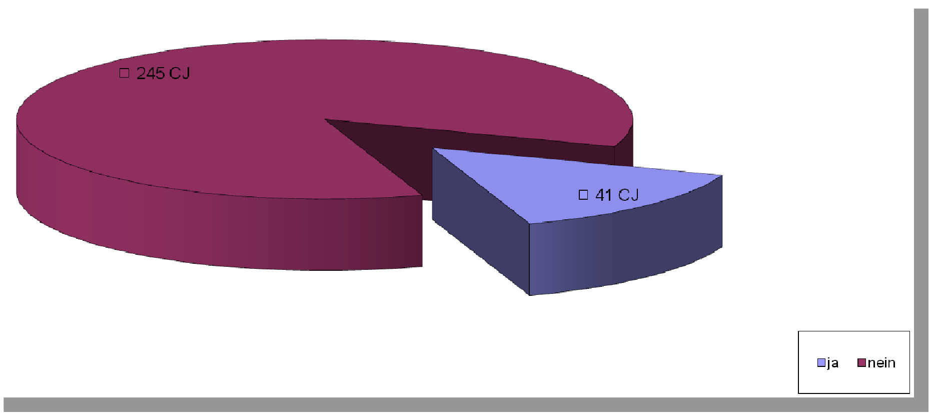

Figure 4: 14.34% of the CJs are critical because they are facing a considerable change of the tasks and thus qualification.

Therefore, for about one fourth of the positions there is an urgent need for action since personnel bottlenecks and, thus, knowhow losses are imminent here.

Qualitative evaluation at a glance

The qualitative evaluation of the results led to 6 higher-level fields of activity to which we will have to respond within the next few months:

1) Preservation & acquisition of knowledge

2) Organizational development

3) AREVA career

4) Critical groups of employees

5) Attractiveness of the critical jobs

6) Responsibility

Questions which generally determine the critical jobs discussion:

- How can we plan the personnel placement in such a way that the time required for identification and recruitment on the external labour market can be ensured?
- How can we first exploit all internal options and resources before going on the external labour market?
- How can we strengthen our internal & external image as "preferred employer"?
- How can we plan internal measures (such as job rotation, job enlargement, etc.) in such a way that we "accelerate" development, unlike in the past?
- How can we succeed in the cross-unit transfer of knowhow & talents?
- How can we preserve our experiences (knowledge management)?
- How can we organize in such a way that we accomplish more with the same resources?
- How can we become more efficient & effective without a staff increase?
- Where and how can we set personnel priorities for the benefit of all?
- How can we ensure that we do the right thing*?
- How can we ensure that we do the right thing* properly?
- How do we keep the helicopter view "cross-regionally"?

NUCLEAR EDUCATION IN THE NEW ERA - CASE FINLAND

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ABSTRACT

A new era of nuclear energy is starting. In many respects we can talk about a restart, as is shown by the historical development of nuclear generating capacity. The nuclear builders and experts that originally built the presently running nuclear fleet have retired or are on the verge of retirement. Additionally, the operating environment has changed significantly from the days of the first nuclear energy boom: open competition in electricity markets, subcontracting chains of construction companies, environmental impact assessments, just to name a few examples.

Besides the need to replace the retiring experts with a young generation, new nuclear builds mean an additional demand for expert staff. It must be borne in mind that the demand is not only for experts on specific nuclear issues like reactor physics or nuclear fuel, but also more generic issues like structural materials, electronics, automation, radiochemistry etc. Experts on these areas need to be educated on the specific requirements of nuclear safety to a sufficient extent.

How can a small country like Finland tackle the challenges of the new nuclear era? Finland has four power reactors running, one under construction, and two under preparation, after a positive decision-in-principle by the Finnish Parliament in 2010. Also, the decision on the repository for spent fuel is approaching in 2012. The Ministry of Employment and the Economy (MEE) launched a project to survey the know-how in the nuclear field in Finland. A part of the project is to review the education given by Finnish universities and polytechnics in the areas relevant for the nuclear field. The survey also covers training given by different Finnish stakeholders. Besides personnel also the R&D and nuclear infrastructure is assessed.

The MEE project was scheduled for the first half of 2011, but the deadline has been extended to September. Our belief is that the case of Finland can be generalized to other small countries that do not have full-scale nuclear industry of their own, covering the full range from design and construction to operation and decommissioning.

1. Introduction

The scientific community emphasizes the importance of low carbon emissions in energy production. This is necessary for limiting the consequences of climate change and also to save hydrocarbon resources for future generations. One of the low-carbon options is nuclear energy that can provide baseload electricity at competitive price. The share of nuclear power of the global electricity demand is currently about 14% and this figure is expected to increase in the coming decades.

Historically, nuclear power was largely commercialized in the 1970's. Twenty new reactors reached criticality each year during the decade. However, the number of new projects decreased significantly in the 1980's, leading to a decline and stagnation in the 1980's and 1990's of the nuclear power industry.

A new era of nuclear energy started in the beginning of the new millennium. It can even be called a restart in many countries. New nuclear energy projects have started or have been planned in the world, especially in Asia but also elsewhere. In Europe, Finland and France have been the first to start new NPP projects, while others are still considering the pros and cons.

Due to the two decades of stagnation, we are facing challenges in the restart. The operating environment has changed significantly from the days of the first nuclear energy boom: open competition in electricity markets, subcontracting chains of construction companies, environmental impact assessments, immensely increased documentation needs, quality requirements, etc. The most significant challenge is, however, the new legions of experts that are needed to replace the ones who originally built the presently running nuclear fleet and who have retired or are on the verge of retirement.

Besides the need to replace the retiring experts with a young generation, new nuclear builds mean an additional demand for expert staff. It must be borne in mind that the demand is not only for experts on specific nuclear issues like reactor physics or nuclear fuel, but also more generic issues like structural materials, electronics, automation, radiochemistry, requirements engineering etc. For example, digital I&C systems pose completely new demands. Experts on these areas need to be educated on the specific requirements of nuclear safety to a sufficient extent.

2. Nuclear energy in Finland

In Finland, the energy consumption per capita is one of highest in the world. This is due to energy-intensive industry, cold climate, long distances and a high standard of living. The palette of primary energy sources is versatile, with various fossile fuels covering half of the consumption and nuclear power one sixth. The share of domestic nuclear power in electricity supply is 25%. [1]

The four current NPP units, two at Loviisa and two at Olkiluoto, started operations within a 5-year period in 1977-82. The Loviisa reactors, VVER-440 model with western safety systems, are operated by Fortum and their current output is 488 MWe each [2]. The Olkiluoto reactors are Swedish design BWR's with a current output of 880 MWe each and operated by TVO [3]. After a few learning years, the performance figures like capability factor of and cumulative dose at these NPP's have consistently been among the best in the world. This has been attributed to optimization of annual outages and proactive maintenance.

In May 2002, the Finnish Parliament ratified the positive Decision-in-Principle (DiP) on a fifth power reactor, applied by TVO. An Environmental Impact Assessment (EIA) procedure was a necessary prerequisite for the DiP and it had been completed in year 2000. After the positive DiP, TVO chose the French-German EPR among several candidates and applied for a construction permit. It was granted in 2005 and the construction of the Olkiluoto-3 unit started right away. The current estimate for start of operations is late 2012, some three years after the original schedule.

In 2007, three power companies started EIA's for a new nuclear power unit: TVO, Fortum and a newcomer Fennovoima [4]. The DiP applications followed in due order and they were handled in one batch by the Government. Finally in April 2010, the Government gave two positive DiP's, one for TVO and one for Fennovoima, and a negative one for Fortum. The decision was ratified by the Parliament in July 2010, after which the power companies started their preparations for model selection and construction permit application.

An important condition for the positive decisions has been acceptable arrangements for nuclear waste management. A national policy was made already in the 1980's and it has been followed by the licensees and the regulatory bodies. In practice, the funds for waste management and decommissioning for the operating units have already been collected from the power companies. TVO and Fortum have established a separate company, Posiva Oy, for the disposal of spent fuel, while the operational waste is already being disposed in bedrock repositories at the NPP sites.

3. Nuclear education in Finland

Many kinds of experts are needed at a NPP and they are educated at different university units and polytechnics. After recruiting a fresh graduate from a generic technical or non-technical field, a power company usually needs to train the person to the tasks. An important part of the training is given by senior experts, giving an apprentice-type position to the

recruit. This method aims to transferring the existing knowledge, important in the generation change but also in the expansion.
An academic degree in nuclear engineering is possible to obtain in two Finnish universities, Aalto University (former Helsinki University of Technology) [5] and Lappeenranta University of Technology [6]. They are both effective members of the ENEN Association since its beginning. Finland obeys the Bologna system in university studies. The courses directly related with nuclear energy are concentrated in the Master studies of 120 ECTS where the extent of these studies is 60-100 ECTS of the total.
Typically, a total of 15 Masters in nuclear engineering, and some five Doctors or Licentiates, graduate annually from these two universities. When the student volumes are so modest, special assignments, project works and the thesis work comprise a major part of the nuclear-related studies instead of basic lecture courses. This is actually an efficient way of creating expertise already before graduation, since these individual studies are made under direct supervision of experts at power companies, research institutes, and university research groups. The ENEN network is utilized as a complement.
Additionally, radiochemistry is taught at the University of Helsinki [7]. The curriculum is extensive in European standards and the studies are related with research on nuclear waste management, environmental radiochemistry, and radiation chemistry. Annually four Masters and one Doctor are graduated from this programme on the average. The University of Helsinki participates in the CINCH project aiming for European cooperation in radiochemistry education and training.
Many research areas are involved in nuclear waste management. Research on these subjects is pursued at various universities, including Aalto University, the University of Jyväskylä and Åbo Akademi.
A significant fraction of the nuclear experts continue their studies after Master's thesis. Graduate studies have been traditionally completed in research projects at different stakeholders, not only universities. Especially the role of the Technical Research Centre of Finland (VTT) is important in deepening the expertise of young Masters. From the beginning of 2012, a new national doctoral programme of nuclear engineering and radiochemistry (YTERA) will inaugurate, with the goal to increase the volume but also to clarify the structure of doctoral studies and add cooperation between universities.
The research groups at Finnish universities participate in both domestic and international research programmes that are utilized for competence building. The main domestic programmes are those on nuclear safety (SAFIR) and waste management (KYT). Additionally, the Academy of Finland is running a sustainable energy research programme SusEn in 2008-2011 and a Gen-IV fission research project NETNUC is included in the programme.
The special characteristics of the nuclear energy field need to be explained to new recruits on the field, especially to non-nuclear engineers. A need for a national training course on nuclear safety was realized in 2002 and preparations for its implementation started right away. The first course YK1 started in 2003 and the YK8 course was finished in March 2011. The course is currently 21 days long in 6 periods of 3 or 4 days each. The number of participants has been 50-60 annually, so over 400 fresh experts have taken the course by now and YK9 is under preparation.
A similar approach has been started on nuclear waste management area. A national pilot course of 2.5 days was held in 2010 for 20 students and fresh graduates representing universities, research institutes and other organizations in the field. The goal is to extend the course to 5 days and arrange the course annually. The Finnish organizations also participate in the PETRUS2 project on the European level.

4. Survey of know-how

When ratifying the positive DiP's in 2010, the Parliament presumed that sufficient expertise is available to implement the projects. The Ministry of Employment and the Economy (MEE) launched a project to survey the know-how in the nuclear field in Finland in October 2010. A similar survey was made in 2000, but in a substantially different environment, and it was briefly updated in 2005 after the Olkiluoto-3 project started. The current project covers all stakeholders in the field and aims at a comprehensive survey of the current situation as well as reliable estimation of future needs.

An essential tool of the MEE project is a web-based survey that has been sent to all Finnish organisations in the field, also including contractors and suppliers of power companies. This survey aims to review the education given by Finnish universities and polytechnics in the areas relevant for the nuclear field and also training given by different Finnish stakeholders. Besides personnel also the R&D activities and nuclear infrastructure are assessed, with a separate task on the status of the research reactor of VTT. A separate work package is also included for mapping the possibilities of Finnish companies to participate in the coming NPP construction projects more extensively than in the Olkiluoto-3 project.

Each European country has its own peculiarities related to nuclear energy, often attributable to historical developments. However, our belief is that the case of Finland can be generalized to other small countries that do not have full-scale nuclear industry of their own, covering the full range from design and construction to operation and decommissioning. The reality is very different from the big countries.

The MEE project was scheduled for the first half of 2011 and the plan was to present preliminary results in this paper. However, the implementation of the survey turned out to be a more extensive job than expected. Additionally, the consequences of the giant earthquake that struck Japan on Friday March 11th reshuffled the priorities in nuclear organizations also in Finland, leading to additional delays in the project. The current plan is to finish the MEE project in September 2011. Its final report will be translated to English.

5. Conclusion

Introducing nuclear energy in a national energy palette means a long commitment. It takes a decade from the beginning of an EIA procedure to start of commercial operation - in the optimum case. Most current reactor models are planned for a 60-year service life after which decommissioning takes another decade. Disposal of spent fuel continues several decades after this. In Finland the current plans span to 2120's and beyond.

National cooperation is a prerequisite for a successful nuclear programme. Different stakeholders have different agendas, but the number one priority for all is safety. Cooperation between universities, research institutes, power companies and authorities is possible in the neutral fields like education, training and safety-related research, and in a small country like Finland it can possibly be reached easier than in bigger ones.

Nowadays, young engineers have many other career possibilities than nuclear energy, so the competition of capable labour is harder then in the 1970's. In order to attract talented young professionals to the field, they must be given a possibility to participate in interesting projects. At research institutes and universities, research on Gen-IV and fusion reactors offer a good challenge. In power companies, new plant projects are naturally attractive to experts, but modernization projects can substitute them.

The energy sector is not only a technical one but also a political playground. A successful restart of the nuclear energy era is possible only with public acceptance. This requires long-term commitment on informing the media and public on nuclear-related issues in a timely and honest manner. According to the Finnish example, this is not a mission impossible.

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RECRUITMENT AND PREPARATION OF EMPLOYEES FOR NPP

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ABSTRACT

By the year 2020 the CEZ Group needs to recruit above seven thousand graduates of technical studies for the construction and operation of new production sources and for rejuvenation of the aging personnel in energy production and distribution. This situation concerns two nuclear power plants and a planned construction of two new units of NPP Temelín. Increased recruitment targets, in the context of a lack of graduates from technical schools and universities, including specific requirements for workers in the nuclear field require a comprehensive approach that is beyond HR processes and includes public relations and marketing activities as well.

Each candidate for a job at NPP must meet prescribed standards of medical and psychological fitness, education, degree and criminal integrity requirements. During the on boarding phase, the candidates enhance their professional competence for carrying out activities at NPP. The training is intensive and relatively long and depends on the job and its description, as well as on the list of required qualifications that apply for the position.

In this paper we present our approach towards recruitment and nuclear training.

1. Introduction

By the year 2020 the CEZ Group needs to recruit several thousands of graduates while the number of technical graduates in the Czech Republic is steadily declining. Recruitment of technical experts is more and more challenging due to the demographics downward curve and a limited interest of students in technical fields. This trend is confirmed by an analysis of the National Educational Fund, which claims that the Czech Republic will miss up to 14 000 new technical graduates in 2016 in the energy industry for personnel rejuvenation.

The vision of the HR policy of the CEZ Group is to create personnel tools and processes for permanent arrangement of needs in the field of qualified, motivated and professionally skilled employees, in compliance with the company culture, safety and best practices (Instruction of the director ČEZ_PR_1038 – Personnel Policy ČEZ, a. s.).

The HR Division provides ČEZ, a. s., therefore Dukovany and Temelin Nuclear Power Plants (hereinafter referred to as NPP Dukovany, Temelin or EDU, ETE) with recruitment, selection and appraisal of employees within the process of training in compliance with valid legislation of the Czech Republic, requirements of supervising Czech authorities and recommendation of the International Atomic Energy Agency and WANO. A significant part of NPP employees have a university degree or have attended a secondary specialised school. Due to these reasons, we can focus NPP personnel preparation at completion of specific knowledge in the field of nuclear power plant and obtaining practical knowledge and skills needed for their work performance.

Special attention is paid to the selected employees from the point of view of nuclear safety (control room operators, shift supervisors, safety engineers, control and operational physicists) and radiation protection. One of the selection criteria is NPP-operation and safety culture compliant psychological profile of NPP employees.

2. Recruitment strategy and key activities to enforce recruitment

The lack of qualified staff potentially represents a risk for fulfilment of long-term goals for the CEZ Group, including the key project of building a new nuclear power plant. Therefore, the CEZ Group has decided to launch a strategic recruitment project, whose goals are:

- Motivate young people and their parents to study at technical colleges;
- Increase the attractiveness of technical studies in the public's eyes;
- Strengthen the loyalty of graduates to the technical field;
- Employ young technicians at CEZ.

Our target group consists primarily of students and graduates of secondary schools and technical universities. We are aware of the fact that success also depends on systematic cooperation with the management and teachers of selected secondary schools and universities, students' parents, government institutions such as the Ministry of Education, the State Office for Nuclear Safety and other state institutions and professional associations.

The strategic recruitment project innovates, integrates and builds upon a number of previously existing recruitment activities: meetings between students and professionals at all levels of schools, financial support for teaching instruments for teaching physics and school equipment (incl. VR-1 training nuclear reactor), company presentation at university open days and job fairs, excursions and work experience for students, scholarship programs, student projects and competitions and other similar activities. We have focused on increasing the intensity and improving the content of these activities.

It is worth noting that our special internships bring students closer to working for the energy industry. Students from secondary schools can attend "Energy graduation": in three days the participants are acquainted with nuclear or conventional power plant operation or distribution facilities. Furthermore, for students of technical universities with an interest in nuclear energy we offer an opportunity to participate in a 14-day training program in NPP Temelín and Dukovany called "Summer University". During these activities, we perform a pre-screening of students who are interested in working for the CEZ Group and would be suitable candidates for specific position related to NPP operation.

In order to organize the communication with educational institutions, the CEZ Group has started to build a partnership network with secondary schools and universities. At this moment we have established cooperation with 46 secondary schools and 13 university faculties in CZ. The aim of this cooperation is to improve the quality of technical studies and engage young engineers during their studies. The CEZ Group also supports activities leading to opening new study fields whose graduates would be properly prepared for the energy industry.

To meet the main goal of strategic recruitment, i.e. to recruit the required number of qualified employees within a particular period of time, we had to optimize the process of long-term human resources planning. Based on the information from internal customers we have defined middle and long-term requirement forecasts for human resources needed for the construction of new NPP, as well as operation of the current NPP. Thus, planning, recruitment, training and migration of employees especially related to NPP construction and operation starts to be systematically coordinated. Our prediction of human resource needs has extended from 5 to 10 years.

To support recruitment of technical experts with a very specific profile a referral bonus system was developed. This system allows active participation of all our employees in the presentation of the CEZ Group as a preferred employer.

Marketing and PR support of recruitment helps us convince young people that technical studies are attractive and that they should be interested in a career in the energy industry, preferably in the CEZ Group. A unique employee brand has become the basis of communication activities. We communicate why to work in the CEZ Group and why to be proud of it. The developed brand mark "CEZ – Kde jinde" (*Lit. CEZ – where else…*) says that the CEZ Group has a unique growth potential and offers unique job opportunities.

Through intensive cooperation with media we are continuously trying to influence the attractiveness of technical studies and work in the energy industry. For example, one of the first communication activities aimed to students of technical schools was a knowledge competition introducing energy industry, activities and employment opportunities in the CEZ Group. Our new interactive website presenting "the world of the CEZ Group" has been viewed by over 15 000 students. Over 2 600 students have actively participated in the contest and initiated a communication with us.

We have also started to use other communication channels, such as a special Facebook page, a newsletter for students and candidates for a job that delivers news, lists of vacant positions, video chat, profiles of interesting professions, etc.

3. Legislature

ČEZ, a. s. carries out the recruitment, selection and classification of its employees for the training process in compliance with the valid legislation of the Czech Republic, the requirements of the Czech supervisory bodies, the recommendations of the International Atomic Energy Agency and good practices from NPP operators worldwide.

Act No. 18/1997 Coll. (dubbed Atomic Law)	On the peaceful utilization of nuclear energy and ionising radiation

It is authorized by the Czech regulatory body – the State Office for Nuclear Safety to issue an implementing regulation.

Regulation No. 146/1997 Coll.	Specifying the activities having a direct impact on nuclear safety and activities relevant to radiation protection

This regulation stipulates requirements for the qualifications and training of selected employees - licensed personnel (employees performing the above-mentioned activities), a method for examining their special professional competence, licensing the selected employees to perform such activities, and a method of preparation of approved documentation permitting the training of selected employees.

4. The Training System and Programmes

The concept (system) of training for the NPP staff is based on the control area P04, is guaranteed by the Training and Development department and is described in company internal documents. The stated documentation also sets the competencies and responsibilities of departments and individuals for specific processes and activities. The aim of the training for NPP staff is to obtain and maintain competence of the employees to perform their work-related activities.

4.1. General Employee Training (GET)

The aim of this training is to provide each new NPP employee or external contractor with the most important information necessary for entry and work on the particular site. The training focuses on: basic information about the NPP – principle of electric power generation, layout, organizational structure; physical protection; industrial safety and health protection; nuclear safety and safety culture; fire protection; radiation protection; emergency preparedness; environmental management system and waste handling; quality management; maintenance work management and hoisting machinery.

4.2. Initial and Continuing Training

The aim of this training is to deepen the employee's knowledge, skills and practices and to provide specific knowledge and practical experience of NPP. This training is carried out in line with approved training programs specific for each group and employee specialization, and is divided into:

- Initial training up to the level of the “Certificate”;
- Initial training up to the level of “Authorization”

The initial training up to the level of the “Certificate” of NPP personnel consists of self-contained modules (the duration of modules ranges from 1 to 8 weeks) and theoretical lessons alternate with educational stays (OJT) at the nuclear power plant.

The participants' knowledge is tested by subject exams during their training, and the training is completed by final exams to acquire the “Certificate”.

The aim of the initial training up to the level of “Authorization” is to achieve the professional level required for the performance of work at a NPP based on the completion of other specialized courses, theoretical and practical trainings at the power plant. The quality of the knowledge gained is tested by examinations and certified by an issue of “Authorization” on the completion of training.

The diagram of initial training for Control Room Operators is presented in Figure 1.

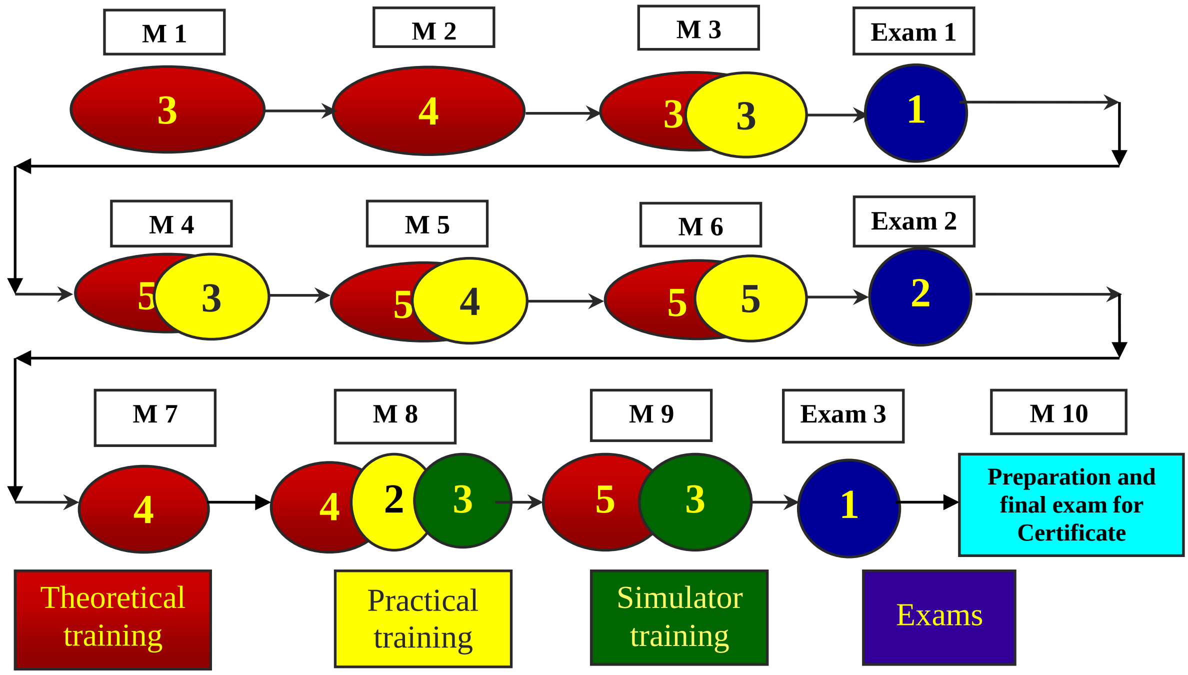

Figure 1

Preparation for work change is a special form of Initial training, aimed at extending the knowledge and practical experience acquired so far with other specific knowledge, skills and practices necessary to cover the difference with respect to the performed work. Its content is determined by comparison of the training programs for the original and new group of training and specialization. Knowledge testing is similar to the testing conducted in the Initial training.

The aim of Continuing Training is to retain, refresh or deepen the employees' specific professional abilities necessary for the performance of their current work. For NPP operation personnel, this training is usually carried out in the form of the so-called training days. The respective specialists train NPP staff in topics in accordance with qualification requirements and training needs. Training days for other employees are arranged by their line managers in the areas of, to mention some of them, industrial safety, environmental management system, fire protection, physical protection, feedback from operational experiences, emergency preparedness, technology modification, documentation changes.

4.3. Simulator training

The personnel training on simulators in NPPs Dukovany and Temelin is performed for two groups of employees: for licensed staff - control room operators, shift supervisors and safety engineers, and for other specified personnel – service staff of the operation equipment (field operators, mechanics, etc.), operational physicists and members of the technical supporting group of the emergency staff (TSG).

For the licensed staff, the simulator training is included in their initial and continuing training, including preparation for work change. The program of all the types of training is prepared on the basis of training programs and includes tasks from the area of standard operation of the unit as well as abnormal and emergency unit situations. The training is assessed and registered. The extent of individual training types is as follows:

- Initial training – 9 weeks in total
- Continuing training – 2 weeks / year
- Re-qualification between functions – 1 or 2 weeks depending on the function.

Within the scope of training of individual units modernisation, a special re-qualification training is currently being organized for the staff of the relevant unit control room operators, shift supervisors and safety engineers. The extent of such simulator training is 5 days.

The other specified personnel participates in simulator training only within the scope of their initial training (field operators for the secondary circuit and electro equipment) and within function performance. In the latter, they participate in continuing training of the licensed personnel and they co-operate with the control room operators while performing selected tasks. This relates to service operation staff (field operators), operational physicists and TSG members.

4.4. Other trainings

4.4.1. The aim of vocational training is to deepen, complement and sustain yet acquired professional knowledge, skills and habits, so that the employees satisfy the requirements of professional competence in order to perform their work. This includes, for example, courses for electricians, welders, crane operators, chemistry workers, flaw detection and metrology, language courses or courses in safety and quality.

4.4.2. Training of Contractors covers some of the following activities:

- General Employee Training and tests examining general competence for entry and starting of work on the site (see GET)
- Initial training and tests examining competence for independent movement in the radiological controlled area (RCA) and work on the open primary circuit
- Initial training for managers
- Continuing training and test examining competence for entry on the site – workers
- Continuing training and test examining competence for entry on the site – leaders
- Continuing training and tests examining competence for independent movement in the RCA and work on the open primary circuit
- Training for work with PassPort system

4.4.3. Soft Skills Training and Management Development includes a wide range of trainings in the area of communications, team leadership, the decision process, self-management, etc. One basic characteristic of each training session is that it has a tailored design which meets the precise requirements of the department and employee(s). For main control room staff we have prepared and implemented a development program "Bez stresu a bez rizika" (*Lit. No Stress - No Risk)* which develops skills and talent needed to underpin the safety of power plant operation; the teaching methods are interactive (experience learning, outdoor, simulation). For the development of managerial potential and development of managers we have prepared two special programs: ČEZ Leader for NPP and ČEZ Manager. The aim of the ČEZ Leader for NPP program is a systematic preparation and development of the participants' individual managerial potential for possible future employment at managerial positions within the NPP. The ČEZ Manager Development program – enhancing performance through aware leadership is intended for managers in the middle-management.

5. Conclusion

NPP operation, training and development activities and strategic recruitment activities are mutually dependent and coordinated.

The training and development of employees is an integral part of the NPP operation system. The department for Training and Development coordinates knowledge management and provides the complete professional training of NPP employees and contractors. Proper qualifications are vital for competent and safe NPP operation. A well selected and trained personnel has a key role in prevention of abnormal situations and is the best guarantee that, if it happens, such situation will properly be handled.

Employees with excellent high school and university education, management of knowledge and learning from own and external experience are areas of major and continuous interest NPP of Dukovany and Temelín.

Supply of smart technical students with a suitable psychological profile is one of the major goals of the Department for Strategic Recruitment. Although the strategic recruitment project is a long term activity, it has already brought the first positive results. Thanks to the huge amount of activities that increased the attractiveness of the CEZ Group, in June 2010, the Trendence Institute survey highlighted CEZ as the most desirable employer for students of technical and economic objectives, while in the autumn of the same year, CEZ won 1st place in The Most Desired Employer of the Year in the Czech Republic.

THE IMPORTANCE OF RESEARCH REACTORS FOR NUCLEAR EDUCATION AND TRAINING : TRAINING COURSES DEVELOPED ON ISIS REACTOR

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ABSTRACT

The National Institute for Nuclear Science and Technology (INSTN) is a higher education institution. Its objective is to provide to engineers and researchers a high level of scientific and technological qualification in disciplines related to nuclear engineering. At the very beginning, in the 60's, the adopted strategy was to complete theoretical courses by lab-work and training courses on a nuclear research reactor. We present here the training courses that were developed on ISIS reactor at CEA Saclay research Centre for this purpose, their associated education programmes, as well as the feedback obtained from the trainees.

1. Introduction

As a part of the French Alternative Energies and Atomic Energy Commission (CEA), the National Institute for Nuclear Science and Technology (INSTN) is a higher education institution under the joint supervision of the Ministries in charge of higher Education and Industry.

The institute was created in 1956, when France decided to launch a nuclear programme. Its objective was to provide to engineers and researchers a high level of scientific and technological qualification in all disciplines related to nuclear energy applications.

Today, the institute offers both National, European and International academic degree programmes for students, engineers and technicians, as well as continuing education courses for professionals and PhD students.

Since 1956, the adopted strategy is to complete the education, training and qualification programmes with lab work and training courses carried out on nuclear facilities, including research reactors. In particular, courses carried out on nuclear reactors ensure a practical and comprehensive understanding of the reactor principle and operation that cannot be gained only with the use of simulators.

Moreover, empathies being given to the impact of each operation and effect on the safety and security of the reactor design and operation, these training tolls enhance the background of the trainees in nuclear safety.

After a description of ISIS reactor, we present in this paper the training courses that were developed on this reactor together with their associated education and training programmes. We also focus on the feedback obtained from the trainees concerning the use of ISIS reactor as a toll for education and training.

2. ISIS reactor description

ISIS reactor is an open core pool type reactor with a nominal power of 700 kW. It is the neutron mock up of OSIRIS research reactor situated in the same facility and which exhibits a thermal power of 70 MW.

The schematic of the reactor pool and the water primary and secondary circuits is shown in figure 1. The pool of ISIS reactor is 7 meters deep. At the bottom of the pool, a big metallic piece called the base sustains the core of the reactor. The core, with a section of 62 cm x 70 cm, is composed of an Aluminium box with 56 cases. It contains 38 fuel assemblies, 6 control rods, 7 Beryllium assemblies, as well as 5 experimental cases. The MTR fuel, in silicide U_3Si_2Al form, is enriched at 19.75%. The beryllium assemblies are used both as neutron reflector, to reduce neutron leakage on one side of the core, and as the starting neutron source, through (γ, n) reactions. The experimental cases can be used to place devices to be irradiated or tested (instrumentation, samples to be activated, test fuel, …). Above the core a stainless steel chimney separates the water from the primary water loop from the rest of the pool. A gate, which is place on one side of the chimney, can be removed to load or unload fuel assemblies of experimental devices between the poll and the core. Figure 2 is a photograph of the top of the pool in the reactor hall, during the reactor presentation to students.

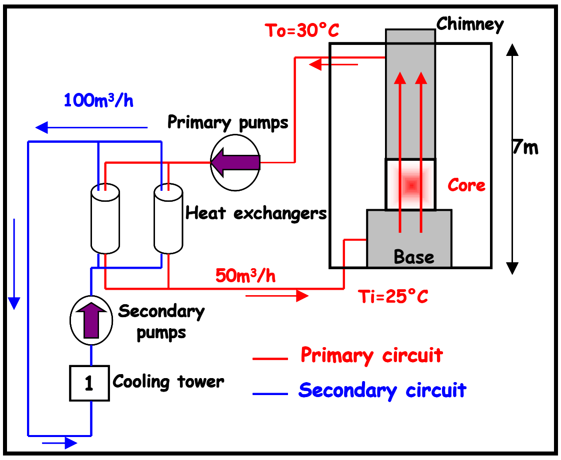

Figure 1: ISIS reactor pool and water circuits.

Figure 2 : Photograph of ISIS reactor

From 1967 (first start up) until 2004, ISIS reactor was mainly used for the test of new OSIRIS core configurations, for power cartography measurements, as well as to supply neutron and gamma fluxes for experiments carried out in the core or in its periphery.

From 2004 till 2006, the reactor went through a major refurbishment of the control system and control room in order to use ISIS reactor for education and training activities. This project was carried out on the basis of the background gained on ULYSSE reactor, which was ran by INSTN, from 1961 till 2007, for education and training activities.

This background was used to define the specific modifications of the control system for the education and training activities, which came in addition to the "standard" refurbishment of ISIS control system. The modifications concerned, in particular, the logic of the safety system, the control system hardware, the ergonomics of the control board and control room, as well as of the development of a super-vision software.

For example, the logic of the safety system was modified to enable the individual drop of each rod during standard reactor operation. A major improvement also concerned the extraction of the measured signals during reactor operation for their use by a super-vision software that displays different screens showing the evolution of chosen reactor parameters for each type of experiment done on the reactor.

After the refurbishment, ISIS reactor became, from March 2007, the main reactor used by CEA for the education and training activities.

3. Education and training on ISIS reactor

An extensive set of experiments have been developed on ISIS reactor for education and training. Experiments cover the following topics :

- the control of the reactivity during fuel loading,
- the approach to criticality,
- the reactor start up and power stabilisation,
- the study of the influence of the precursors in fast power variations,
- the influence of experimental set ups on the core reactivity,
- the study of the influence of the quantity of moderator on the core reactivity (sub and over moderation),
- the establishment of the calibration curves of a rod (by doubling time measurements),
- the measurement of the worth a rod by the rod drop technique,
- the study of the temperature effects (temperature coefficient value, self-stabilisation),
- the study of the operation and the setting of the neutron detection systems,
- radioprotection measurements around the reactor,
- the operation of the reactor under the supervision of the reactor operation team,
- neutron flux measurements (neutron detectors and neutron activation),
- nuclear analysis of activated samples.

In prelude to the experiments, a presentation of the reactor is made, which includes the description of the reactor on a PowerPoint presentation and a visit in the reactor hall to show the structure of the pool and the core. It can be in some case completed by a visit of the 70 MW OSIRS reactor hall and control room, as well as the hot cells that are used for the manipulation of irradiated materials.

The duration of a course on ISIS reactor is 3 hours. Depending on the topic of the course, one or several experiments can be carried out during a 3 hours course. Nine different courses have been developed. Their integration into education and training programmes developed at INSTN is discussed in the following paragraph.

4. Integration into education and training programmes

INSTN is involved both in academic degree programmes and continuing education courses for professionals.

Concerning the academic degree, training courses on ISIS reactors are addressed to students and engineers from different institutions at a national and international level. This includes training courses carried out in the frame of :

- an international master in Nuclear Energy which is organised at INSTN in collaboration with other universities and engineer schools,
- a one year specialisation course in Nuclear Engineering which was developed by the INSTN in 1956 and contributed to the qualification of up to 140 engineers every year since this date,
- nuclear engineering modules of various master and engineer degrees in which the INSTN is involved,
- a collaboration agreement between Sweden and France that ensure the financial support for the organisation of 12 training session (2,5 days) on ISIS reactor for students from three Swedish universities.

Concerning the continuing education for professionals, training courses on ISIS reactors are addressed to a very wide public including researchers, engineers and technicians. This includes training courses carried out in the frame of :

- an 8 weeks course which is part of the qualification and the retraining process for the operators of the research reactors,
- different courses (taught in English or French) organised on a regular basis (at least once a year) and related to the principle, the operation, the safety and the neutronics of nuclear reactors,
- different courses organised by INSTN to respond to the specific need of the nuclear industry and nuclear programs, which includes courses for the personal of the French regulator body, for young engineers from the Italian company ENEL, for project managers of the Vietnamese company EVN (Electricity of Vietnam), or for teachers and professors from several Polish Universities.

Depending on the pedagogic goals, the trainees can follow programmes that exhibit from 3 up to 18 hours of training courses on ISIS reactors. Two programme examples are given bellow.

The most basic training course (3 hours) is intended to give an introductive presentation of nuclear reactor operation. It is carried out in the frame of nuclear engineering basic courses and modules for students and for professionals. This basic course includes :

- a presentation of ISIS reactor,
- the explanation of the approach to criticality method,
- the practical determination of the critical position of the rod by this method,
- the calculation of the rod position to start up the reactor with a given doubling time,
- the stabilisation of the reactor at a power of 500 W,
- the demonstration of the automatic control to maintain the power constant,
- the study of the temperature effects by increasing the power of the reactor to 50 kW, showing the feedback effects due to the Doppler and water expansion effects,
- the demonstration of the power self stabilisation through the temperature effects,
- a practical discussion about the safety of the reactor operation : when and why should we carry out the approach to criticality, what should be the maximum value of the core reactivity for operation, what are the benefit of the temperature effects and what can be their consequence in incidental condition if cold water is inserted into the core.

Another example is an 18 hours programme on ISIS reactor which is carried out in the frame of a 320 hours programme for the training and the qualification of the operators of the research reactors. This intensive programme covers a wide range of the topics described in paragraph 3. It includes a sequence during which each trainee operates ISIS reactor under the supervision of the normal operating staff. For this sequence, the trainee has to learn some basic knowledge on ISIS reactor operation. He follows the operation of the reactor by another trainee, make all the calculations necessary to operate the reactor (position of a rod to obtain a doubling time of 30 s, for example) and finally operate the reactor. The operating sequence includes for example : the reactor start up, the switch from the low level of power neutron detection systems to the high level ones, the reactor power stabilisation at 500 W, the search for another critical configuration of the rods by inserting one rod and compensating it by the extracting another one. Of course, this first experience in the operation of a reactor is only a first step in the qualification process of the operator that further follow an on the job training on their own facility for a few months.

Today, the training activity on ISIS reactor represents about 70 days per year. It is expected to further increase in the next year with the development of the international courses organised by INSTN.

5. Feedback on the training courses on ISIS reactor

The training courses carried out on ISIS reactor are addressed to a wide range of public, French and International public, including students from universities and engineer schools, as well as professionals such as operators of nuclear reactors, engineers, researchers, and personnel from the regulator body.

The feedback obtained from the trainee's shows that the training courses carried on research reactor ensure a very valuable understanding of the reactor theory and operation.

For students and professionals these courses give a great and unique opportunity to get an insight into the reactor physics and they strongly motivate their interest in this domain of science and technology.

For professionals, such as the personnel involved in the design, the construction, the operation and the control of nuclear reactors, the courses give a practical illustration of the operation of a reactor and ensure a comprehensive understanding of the reactor principle and operation that cannot be gained only with theoretical courses and the use of simulators.

Moreover, for the personnel directly involved in reactor operation, empathies being given to the impact of each operation and effect on the safety and security of the reactor operation, both in normal and incidental operation, the courses contribute to a significant improvement in the safety of reactor operation.

6. Conclusion

Since 1956, the National Institute for Nuclear Science and Technology provides to students, engineers and researchers a high level of scientific and technological qualification in nuclear reactor theory and operation. The adopted strategy is to complete theoretical courses by training courses on software applications, simulators and training reactors. Thus a large set of training courses have been developed on ISIS research reactor in the frame of the education and training programmes of INSTN. The experience gained shows that such training courses bring tremendous benefits for all trainees since they ensure a practical and comprehensive understanding of the reactor physics, design and operation. With this feedback, INSTN is continuously developing the use of the training courses on ISIS reactor in its education and training programmes, both for its French and the International courses.

TOWARDS THE CONSOLIDATION OF THE MASTER IN NUCLEAR ENGINEERING & APPLICATIONS (MINA)

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1. Introduction

Nuclear power capacity in Spain is higher than 7800 MWe, which represents around 8% of the total installed capacity and about 19% of the power production. No matter the future [1], distribution of the energy mix, operation, maintenance and even decommissioning of the current reactor fleet, will demand highly qualified engineers and technicians with sound backgrounds to address those upcoming challenges. This need will be fostered by two additional circumstances: globalization, which is already bringing Spanish engineers anywhere in the world where this demand exists (Brazil, Argentina, South-Africa, USA and more); and knowledge preservation at this very moment at which a large number of nuclear professionals are reaching their retirement ages.

In this national and international context, CIEMAT and UAM recognized the opportunity to adopt a new ambitious and encouraging approach in the training of nuclear professionals: the Master in Nuclear Engineering and Applications (MINA). MINA is founded on three basic pillars: CIEMAT experience on educating nuclear professionals, UAM experience on providing academic skills, and, no less important, a tailored format to accommodate the Master to the current needs of the nuclear Spanish sector. In short, MINA was born with a strong professional approach.

The MINA fundamentals have been described elsewhere ([2], [3]). With a duration of an academic year (approximately 1,500 h), MINA provided an exhaustive and extensive vision of the underlying disciplines of the existing and future applications of the nuclear technology. The Master programme, developed through a joint and close collaboration among industry engineers, research institutions and Universities, allowed a practical approach in which individual student projects (500 h) are mostly proposed and supervised by industry staff, so that MINA students become familiar with their environments and tools.

The present article offers a synthesis of the comparative analysis carried out between the first two editions of the Master (MINA-2008 and MINA-2009). The first part is dedicated to the identification of trends between both generations in terms of interest, qualifications and behaviour against the challenges of the Master. The second one analyzes the influence of the methodological changes and a higher importance of the pupils work as fundamental axis of learning. Additionally, the portfolio of the projects carried out in both editions is examined; from it some interesting changes are perceived. Finally, a set of lessons learnt and future actions to be conducted have been synthesized.

2. MINA-2008 and MINA-2009 comparative analysis

This section compares a set of major indicators that describe the two first editions of MINA: participation, academic degrees and student´s response:

- **Participation.** Both MINA editions together, a total of 35 nuclear professionals have been educated. MINA-2008 had 14 students registered to full time Master, 7 less than MINA-2009. In addition, a good number of "partial-scope" students attended a few subjects; in term of "full-scope" students, they meant 4 and 1 additional students. The growing interest in nuclear education is shown by the 50% growth in the number of students participating in the first two MINA editions. Besides, MINA-2010 has been just launched with 25 "full-scope" students. The master is open for students of any nationality and, even though most students are Spanish, students from Chile, Peru, Ecuador and Italy registered as well.

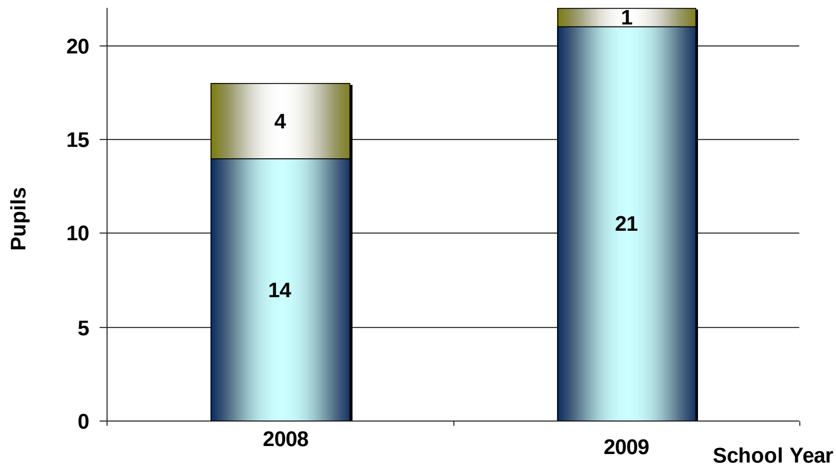

Fig. 1. Number of pupils in both MINA editions

- **Academic Degrees**. In both editions of MINA, engineers and graduates have made up most of attendees, being 92.9 % the first year and 85.7 % the second one. This decrease is compensated by the growth of technical engineers (3-year engineers), who amounted to 14.3 % in MINA-2009. The main difference between both editions is the noticeable participation of chemical engineers in MINA-2009, who were nearly 28 % of the engineers and graduates. The proportion of engineers was kept constant (28.6 %), so that the growth of the new degrees was achieved at the expense of the graduates decrease (64.3 % in MINA-2008 opposite to 33.3 % in MINA-2009). Fig. 2 offers the described distribution of degrees.

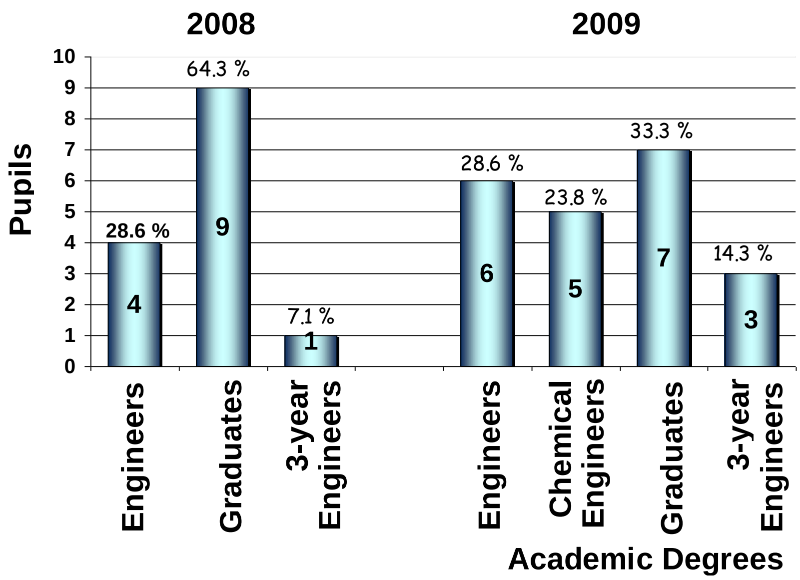

Fig. 2. Academic degrees in MINA-2008 and MINA-2009

- **Student´s response**. An analysis of participants response to the MINA challenges has been conducted; to do so students have been grouped according to their degrees. The results are shown in Fig.3. Several observations can be made: there are no major differences among degrees, except for technical engineers whose marks are slightly under the rest of students; final qualification of MINA look more uniform than subjects since it includes the project evaluation, which in all cases ranged from 8.1 to 8.9 (worth noting that the project weighting factor in the final qualification has been reduced 33% in MINA-2009 – 50% in MINA-2008.

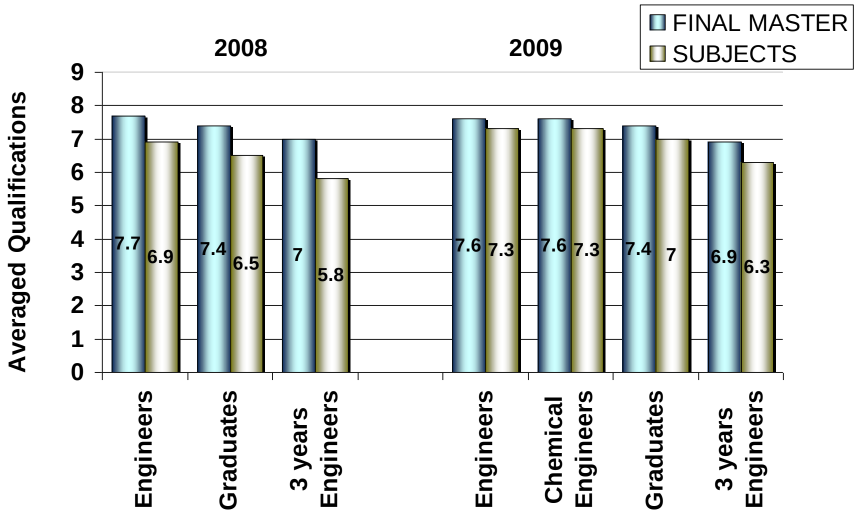

Fig. 3. Averaged qualifications for degrees in MINA-2008 and MINA-2009 editions

A slight improvement can be identified from MINA-2008 to MINA-2009 based on subjects qualifications. This change is too small and it likely comes from external sources other than initial education background or a better assimilation of MINA matters. A potential reason could well be some changes implemented for specific subjects evaluation methods.

Comparison of MINA qualifications and those from the individual background degrees, highlights that 90% of students improved their performance, this being outstanding in around 90%: What is interesting is that it is 3-year engineers the group who experienced a more noticeable improvement. Although a detailed of this observation is not feasible, it is likely that the balanced system of evaluation of MINA and the vocational motivation of the students are major drivers of this trend.

3. Methodological changes

The critical review that the Direction and the Coordination of the Master made after ending of the MINA 2008 edition led to the modification of some aspects where there was room for improvement. Some of them are:

- **Reduction of the number of classroom hours** (Fig. 4). MINA-2009 diminished in approximately 10.7 % the number of hours of classroom with respect to the previous edition. This measure was intended to allow allocating time to foster individual work as much as feasible.

- **Relief of examination stress**. Several measures have been articulated in this respect, like the accomplishment of only one examination in related subjects, the major weighting of other types of evaluation (i.e., exercises, personal works, presentations, etc.) or the not face-to-face response to questionnaires in some introductory matters (as nuclear fusion or sub-critical systems). These measures were orientated to not collapse the agenda of the students by excessive controls.

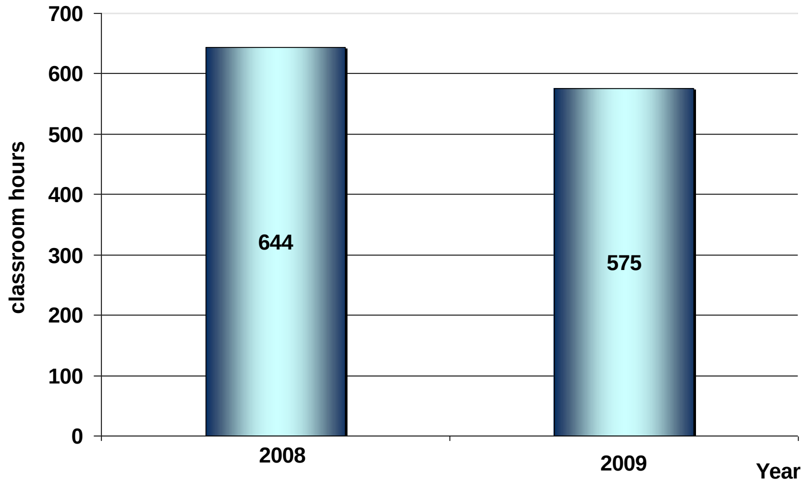

Fig. 4. Classroom hours in both editions of MINA

Both changes, particularly the second one, have possibly influenced in better qualifications in the last edition of the Master (an average of 7.0 in MINA-2009 and 6.4 in MINA-2008). It is significant that 87.5 % of the non pass examinations have been registered in the first quarter of the course, which can be interpreted as a progressive effort of adjustment to the requirements of the Master.

In any case these changes have supposed a decrease of the Master quality. The exigency level of MINA is a fundamental element of his conception and it has been kept till now. In MINA-2008, one participant (7 % of the pupils) had to make a revalidation exam because he did not pass the recovery tests; the pupil did not obtain, finally, the Master title. The number of students in situation of revalidation exam rises in MINA-2009 up to 19 %, in spite of the average improvement in the qualifications of subjects.

4. Project map

MINA-2009 has profited a notable increase of collaboration agreements with the companies and institutions of the nuclear sector for the end Master projects accomplishment. As consequence, the pupils have disposed of a major number and a better endowment of project scholarships. This increase in the contribution of the sector is an indicator of his participative attitude in educational initiatives and, not less importantly, of his positive valuation of the labour realized in MINA.

The participants increase in MINA-2009 (50 %) meant a proportional increase of the projects number. The companies and organizations of the sector took over 85 % of this increase, CIEMAT supplying the remaining 15 % (Fig. 5). It is necessary to emphasize the notable effort made from the beginning of MINA by companies as ENRESA, ENUSA, IBERDROLA and INITEC-Westinghouse, and the incorporation to these activities, in the edition MINA-2009 of CSN, ENDESA SOCOIN and IBERDROLA Engineering (the project of IBERDROLA Engineering is included in the information of IBERDROLA). Other companies and institutions, as SEA Engineering, ENSA or UPM also assumed the project supervision in the first edition of MINA.

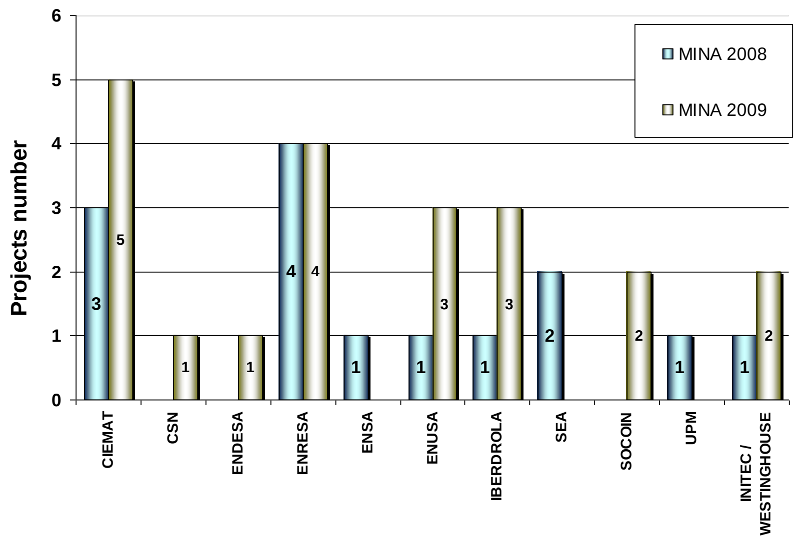

Fig. 5. Companies and institutions that assumed the projects supervision in MINA-2008 and MINA-2009.

In MINA-2009 the main project subjects were again nuclear fuel, dismantling and neutronics (Fig. 6). However, some others, like thermalhydraulics and fusion, have been matters of interest. It should be emphasized the first project conducted on knowledge management, given its innovative nature and importance in the nuclear field. Given that the numbers of projects are limited, areas like nuclear wastes, radiological protection or radiological shielding were not this time considered.

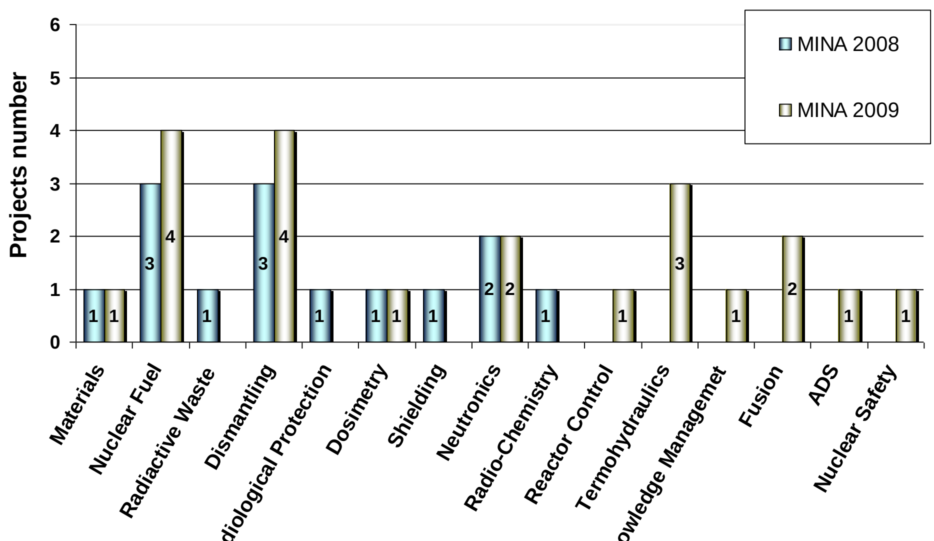

Fig. 6. Subjects matter of the projects in MINA-2008 and MINA-2009

5. Final considerations

In short, MINA is progressing in its consolidation as a reference Master in Nuclear Engineering and Applications. To do so, MINA has kept the original solid foundations, but at the same time it has set up necessary protocols to foster internal and external critical reviews, among which student´s surveys, teacher´s proposals and MINA leading team assessment are major instruments. Thanks to this analysis, the successive editions are incorporating adjustments of contents, modifications in educational and evaluation methodologies and, even, changes of structural nature.

Among the main innovations incorporated in MINA-2010 are:

- Readjustment of thermohydraulics contents and strengthening of practical aspects through student resolution of assignments and computer code sessions.
- Accommodation of classroom time to fit in a full-time format, so that more time may be allocated for individual and or collective work.
- Addition of new practical sessions, either as specific workshops (i.e. computer codes) or/and extending practical contents of subjects.
- Set-up new assessment ways other than pure examinations to achieve a more balanced assessment of student performance. This is particularly important in multi-teacher subjects.

The analysis presented above highlights three major points:

- An increasing interest in the academic domain on nuclear engineering.
- A suitable selection of participants.
- A strong involvement of Spanish nuclear industry.

Nevertheless, in spite of the positive assessment of the Master progress, there are still different actions to do in multiple aspects. Especially, one of the aims for next MINA edition is to obtain more than 90 % of the texts from teachers (at present, approximately 60 %). This aspect is considered of importance to improve the quality of MINA.

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THE UNIVERSITY CHALLENGE: PROVISION OF NUCLEAR EDUCATION FOR THE DIGITAL STUDENT

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ABSTRACT

Nuclear education at university level, whether engineering or science based, must compete against all other STEM based subjects at university level to attract the required number of graduates for the new nuclear build programme, as well as ongoing decommissioning and disposal projects. To meet this challenge UK universities have worked with government and industry to educate an increasing number of graduates, year on year since the turn of the century, through the provision of undergraduate and postgraduate taught degrees and postgraduate research.

The provision of the courses via on-line learning has increased the number of students able to study these courses. Other digital media methods are now being developed to enhance the course delivery, in line with the expectations of the modern 'digital' student. The Nuclear Liaison website (www.nuclearliaison.com) was originally established to provide one point of information for all the nuclear university courses in the UK. Nuclear Liaison TV (www.nltv.co.uk) has now been established to deliver video content to support the courses while also acting as a knowledge management system. To compliment traditional teaching methods computer based virtual reality environments are being utilised to enhance the learning experience. Through a combination of Internet based digital technologies, more students are applying for nuclear courses in the UK and the content and delivery are being provided in a way that is considered the norm for today's 'digital' student.

1. Introduction

During the 1990s nuclear energy in the UK had fallen out of favour due to a combination of cheap north sea gas, the prolonged planning and construction process of Sizewell B, the only PWR in the UK, and the lingering effects on public perception caused by the Chernobyl accident. This downturn was reflected in the universities that taught the nuclear education programmes, with a decreasing number of students and ultimately the closure of courses. Any residual nuclear education was surviving due to the persistence of individuals rather than the support of the higher education institutes [1]. A catalyst for change was required and occurred in the consolidation of BNFL university research funding in four centres of excellence, starting in 1999 with the Centre for Radiochemistry Research at The University of Manchester. This was followed by support for particle technology research in 2000 (University of Leeds), waste management in 2001 (University of Sheffield) and materials performance in 2002 (UMIST/University of Manchester). Student numbers on undergraduate nuclear courses started to increase [1] as students viewed the potential for university nuclear postgraduate projects as well as the brightening prospects in industry.

2. Consolidation and Expansion

High level nuclear expertise was still to be found with the UK Universities but it was spread thinly across many Universities with only a few Universities such as Birmingham, Surrey and Liverpool maintaining continuous nuclear postgraduate taught courses. It was recognised that the nuclear workforce of the future had to be trained somewhere so a consortium of eleven universities [2] and higher educational institutes was brought together with a co-ordination centre based at The University of Manchester. The Nuclear Technology Education

Consortium (NTEC), [3] has the advantage that the students can access any of the 22 modules offered by the now 12 partners. The modules are delivered in a “short-fat” format with the teaching of one module taking place all in the same week. This format also has the benefit of allowing industry-based students to attend as part of their continual professional development.

Previous students employed by industry are now part of an Ambassador’s scheme to act as a contact point between NTEC and the host company. Through a combination of the Ambassador’s and an Industry Advisory Board roadshows are organised to discuss the programme with industry and to allow any potential students to ask questions directly. This proactive approach has enabled the programme to grow in terms of university partners, industry supporters, number of modules and number of students.

Following the success of the NTEC programme a Nuclear Engineering Doctorate [4] programme led by The University of Manchester in partnership with Imperial College London and supported by the Universities of Birmingham, Lancaster, Surrey, Leeds, Strathclyde and Sheffield has been established. This is another close partnership with industry as the doctoral students carry out their research work at the company sponsor. Working closely with industry like this allows the students to understand the commercial context of their work, it also allows the university-industry partnership to foster much closer working relationships than through a traditional industry sponsored PhD programme.

In the last few years several UK universities such as Imperial College London and Cambridge have developed their own nuclear Masters programme while other are following the lead of Lancaster University by establishing undergraduate nuclear courses. This renaissance in university nuclear courses is driven by the requirements of industry with decommissioning in the UK being joined by a new build programme in requiring more and more suitably qualified students.

3. University-Industry Communication

Nuclear universities and the nuclear industry have a long history of co-operation in the UK through the long standing Nuclear Academic Industry Liaison Sub-Committee of the Nuclear Institute. This committee is responsible for a rang of activities such as sponsoring students to attend the annual Universities Nuclear Technology Forum and the awarding of Prizes to the best 5 nuclear Master’s students in the UK. As the number of nuclear universities, courses and students grew it was acknowledged that a further form of communication was necessary to support the bi-annual NAILS meetings. With initial financial support from the Health and Safety Executive the Nuclear Liaison [5] website was established to list all the increasing number of nuclear courses in the UK. The goal was to have one website for all the nuclear courses to make it as easy as possible for potential students to assess and find information on each of the courses. With further HSE funding the website expanded to include a Nuclear Directory of 35 nuclear universities with over 250 nuclear experts. This allows university and industry to identify possible future collaborators.

Nuclear Liaison has since developed further to include a list of industry contacts for graduate training schemes and summer placements, a list of university contacts for course information, a list of other nuclear networks around the world, a list of worldwide nuclear conferences and a comprehensive list of downloadable nuclear reports. It is now established as the web portal for nuclear university information in the UK.

4. Knowledge Management

As the nuclear workforce stagnated in the 1990s recruitment was not a priority, which has resulted in a situation 20 years later that the nuclear workforce is both older and retires earlier than the average UK workforce [6]. As 5% of the workforce is due to retire every year until 2025, with the highest percentage loss in the higher skilled areas, there is real possibility that skills will be lost from the UK nuclear workforce to the detriment of the decommissioning and new build programmes. For any knowledge management programme to be as successful as possible it needs to start as soon as possible. With 52% [6] of the UK nuclear workforce based in the North West of England this was identified by the North West Regional Development Authority (NWDA) as a key issue. A project was initiated to determine an appropriate method of capturing the knowledge before it was lost. A plan was formulated between the NWDA and The University of Manchester to invite senior scientists to deliver lectures on university courses that would be filmed and made freely available via the Internet.

In parallel to this project Urenco [7] had established Urenco TV to inform employees and external audiences about Urenco activities. It was very quickly clear that due to the high level of synergy between the two projects that working together would be very beneficial. This resulted in the establishment of Nuclear Liaison TV (NLTV) [8].

5. A Digital Education Platform

With an experienced film crew and state of the art editing and studio facilities, NLTV is aiming to be the web portal for audio and video content on nuclear issues. Nuclear universities have agreed to allow NLTV access to university lectures to maintain the ambitions and goals of the NWDA/University of Manchester project but developments are also taking place in many other areas. Available on the website are evening lectures from learned societies such as the Nuclear Institute and Institute of Physics, reports from nuclear events, news feeds and podcasts. Following the accident at the Fukushima reactors in Japan in March 2011, NLTV was able to provide links to various news organisations covering the events as well as film and upload a lecture, for online viewing, explaining what had happened at the reactors.

NLTV can also provide promotional videos for industry or universities that can be used to attract more students to consider nuclear courses or careers in the nuclear industry. It is being used to help with knowledge management of the current generation and to enhance the next generation of the nuclear workforce.

6. Virtual Reality for Education

Recent years have seen nuclear courses developing complimentary distance learning options to overcome geographical considerations or work commitments. This development allows a greater number of students to study university courses that previously could not have undertaken such study. Virtual reality environments may be the next stage in distance learning development. For example, The University of Denver, with support from Areva, has built an EPR in the Second Life [9] virtual environment. The simulation allows the visitor to navigate throughout the reactor containment building, Figure 1, showing the reactor pressure vessel, steam generators etc as well as ancillary facilities associated with the reactor. Information is provided at various points around the reactor to educate the visitor.

There is also the possibility of conducting physics experiments in a dedicated laboratory. One example allows the visitor to perform an attenuation experiment using a simulated source and simulated pieces of lead. The data though is real, so the visitor can perform their own attenuation experiment and observe the effect of the attenuation. Further developments are taking place with the model, with the intention that eventually a fully functioning control room will be completed to enable virtual operation of the reactor.

Figure 1 Screenshots from the Second Life EPR Simulation

7. Conclusions

Communication with industry has allowed UK nuclear universities to develop courses of direct relevance and successful recruitment from the courses has encouraged more students to apply year on year. Regular meetings between industry and universities allow the exchange of ideas, which supports development of the programmes to further enhance both the number of students and the content.

Internet based digital content is being used to provide added value to traditionally delivered and distance learning nuclear courses. The use of virtual reality environments can increase the learning experience and provide greater insight for the students, particularly those that do not have access to laboratories. The possibilities are many and varied but the universities must maintain a lead in digital learning for the digital student.

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NOVEL CONCEPTS FOR NUCLEAR TECHNOLOGY EDUCATION AT UPPSALA UNIVERSITY

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ABSTRACT

In the aftermaths of the TMI and Chernobyl accidents, the future of nuclear power was vividly debated in Sweden and a number of political decisions were made with the ambition that nuclear power should be phased out by 2010. Due to this, student's interest in nuclear technology ceased and together with the fact that public funding to nuclear technology was withdrawn, academic research and education within the field were effectively dismounted. Today it is clear that in the foreseeable future, nuclear power together with hydroelectric power will continue to provide the major part of the electricity needed in Sweden and consequently NPP operators have been granted permits to perform lifetime extensions and power upgrades. In June 2010 a landmark legislation was passed that removes the previous dismantlement law and allows permits to be granted for new nuclear reactors of any capacity to replace existing reactors on a one-to one basis.
In order to meet the renewed long-term demand for engineers with a solid understanding of nuclear technology, Uppsala University has formulated an educational strategy along three tracks. First, instead of creating ambitious master's programs in nuclear technology, the already existing engineering programs in a wide range of fields were utilized to expose as many students as possible to nuclear technology. Second, in collaboration with the nuclear industry a programme for commissioned education was initiated with the objective of providing continuing education for professionals within the nuclear industry. The results are encouraging; starting from essentially zero in 2003, typically 100 undergraduate students follows at least one nuclear technology course each year and about 25 students conduct their Diploma work within nuclear technology annually. Meanwhile 100-150 persons/year from the nuclear industry follow the "industrial" courses and an increasing amount of undergraduate students chose to follow also these courses.
Third, with the volume goals being reached, a Bachelor's programme in nuclear technology was launched in the autumn of 2010. The program, which is the only one of its kind in Sweden, has several unique aspects, e.g.: 1) It is an undergraduate programme that is financially supported by the Swedish NPP operators. 2) Academic teachers collaborate with industry experts in most courses. 3) The professional network "Women in Nuclear" provides a mentoring programme with the objective of introducing students to the nuclear industry. 4) Industry facilities such as full-scale simulators and the shut-down Barsebäck NPP are made available for the educational program.

1. Swedish nuclear power

Following the global oil crisis in the early 1970ies Sweden embarked on a large scale expansion of nuclear power. During the period 1972 to 1985 twelve light water reactors at four sites, Barsebäck, Forsmark, Oskarshamn and Ringhals, were commissioned and connected to the electric grid. Following the Three Mile Island accident in 1979 public support for nuclear power declined rapidly and as a result of a referendum about the future of Swedish nuclear power the planning and/or design of new reactors were forbidden. It was also decided that all existing reactors should be shut down no later than 2010. The consequences of these decisions were grave. With no prospect of a long-time career within nuclear industry student's interest in nuclear technology ceased and together with the fact that public funding to nuclear technology was withdrawn, academic research and education within the field were effectively dismounted. During the 1990ies it became clear to the society that nuclear power could not easily be replaced by other sources of energy. and in 1997 an act was passed in the parliament that nuclear power should eventually be phased out, but without a fixed deadline. In the years that followed it became obvious that the remaining ten reactors would be needed in the foreseeable future. Consequently the nuclear power plant operators have been granted permits to perform lifetime extensions and power upgrades. In June 2010 a landmark legislation was passed that removes the dismantlement law of 1997. The new law allows permits to be granted for new nuclear reactors replace existing reactors on a one-to one basis.

2. Swedish nuclear technology education and training

Until recently there have been no Bachelor's or Master's degree programs in nuclear technology in Sweden. Nuclear technology research at the universities has survived and low volume nuclear-technology related post-graduate programs have been maintained at Chalmers, KTH and UU thanks to funding provided by the Swedish Centre for Nuclear Technology (SKC) [1].

With no supply of nuclear engineers from the universities, the nuclear power plant operators have been forced to fulfil their demand for operation and maintenance staff by recruiting primarily technical college graduates and general production engineers with little or no prior knowledge of nuclear technology. Training and education of new staff has been provided by Kärnkraftsäkerhet och Utbildning AB (KSU). KSU, which was formed in 1972 is also operating all Swedish nuclear power plant simulators needed for the training of control-room staff. In view of the on-going life time extensions, power upgrades and the possibility of new nuclear reactors being built it in Sweden it has become obvious that the existing system of training and education does not have the capacity to fulfil the future demand for nuclear power plant staff.

3. Nuclear technology education at Uppsala University

During the last decade Uppsala University (UU) has been hard at work establishing itself as a player in the field of nuclear technology education. In order to do so, the Division of applied nuclear physic at the Department of physics and astronomy formulated an educational strategy along three tracks.

First, rather than creating ambitious master's programs in nuclear technology, the already existing engineering programs in a wide range of fields were utilized to expose as many students as possible to nuclear technology. This has proved very fruitful. Annually, more than 100 undergraduate students follow at least one nuclear technology course. After taking courses on nuclear technology, approximately 25 engineering students each year choose to conduct their Diploma works at one of the Swedish nuclear power companies. In almost all cases these students are offered positions at the companies after graduating thus establishing UU as a provider of high quality engineers to industry.

Second, TK in collaboration with KSU initiated a programme for commissioned education with the objective of providing continuing education for professionals within the nuclear industry. In a long-term agreement TK takes on the obligation to provide courses in, e.g., reactor physics, thermal hydraulics, nuclear chemistry and ionizing radiation and protection at the request of KSU. One element of this agreement that has proved crucial for its success was that KSU recognized that in order for TK to provide high-quality education one had to fund not only the teaching activities, but also to provide funding for the competence development of the university staff involved in the teaching. Commencing in 2003, the commissioned education activities at TK has increased from 9 course weeks per year to 25 weeks in 2010. Some of the contract courses have been made available for UU engineering students. The student participation in the contract courses has proved a big success. Students, often for the first time in their education, get the opportunity to establish contacts with professionals within the nuclear industry. Also, the nuclear industry recognizes that participating students constitute a previously unavailable recruitment basis.

The third phase of the educational strategy comprises the establishement of a Bachelor's programme in nuclear technology as described below.

4. Bachelors's programme in nuclear technology

In contrast to the situation in many other countries with nuclear power, there have never been any nuclear technology programs in Swedish universities with enough capacity to fulfil the demand for staff by the NPP operators. With the exception of a limited number of specialists recruited from Master's programs in nuclear engineering that has recently been established at Chalmers and The Royal Institute of Technology, the nuclear power plant operators have been forced to fulfil their demand for operation and maintenance (O&M) staff by recruiting primarily technical college graduates and general production with little or no prior knowledge of nuclear technology. Therefore new staff has to undergo extensive on the job education and training. With changes in the Swedish secondary school system, technical college educations are vanishing and the nuclear industry has to look to elsewhere for new staff. Increasingly, industry's interest has been directed towards recruiting B.Eng. graduates even though, until now there has been no Bachelor´s programs in nuclear technology at Swedish universities. With this in mind UU approached KSU suggesting that a Bachelor's programme in nuclear technology should be established in order to resolve some of the issues experienced with the old system of education and training:

- In order to shorten the time it takes to educate nuclear power plant operators it is desirable for industry to employ B.Eng. graduates that already have a solid grasp of nuclear technology. After undergoing site-specific training and education provided within industry the new staff should be able to embark on a career as NPP operators.
- Industry faces a huge demand for engineers and technicians within O&M for duties which are not directly related to reactor technology, but rather mechanical and electrical engineering. Again, in order to minimize on-the-job training and education it is desirable that these engineers and technicians have a good general knowledge about reactor technology and its related subjects.
- Because Swedish nuclear power plants are located far from large population areas where most of the big universities are located, industry has experienced difficulties in recruiting and retaining staff. This issue could be addresses if students of mechanical or electrical engineering could be recruited from local universities that by themselves cannot provide this kind of education.

4.1. Programme overview

Commencing in the autumn 2010 UU launched the first Swedish Bachelor's programme in nuclear technology. This was the result of an agreement between the Swedish nuclear power plant operators, KSU and UU where the nuclear power plant operators jointly support the education in a industry sponsorship program. Part of the sponsorship goes to KSU, to conduct simulator teaching, training exercises at the Barsebäck training facility, etcetera within the framework of the Bachelor's program. Thus, industry and academy join forces in a much closer collaboration than hitherto attempted in Sweden. In contrast to industry funded contract education, the university retains the right to decide on, e.g., admission requirements, programme and course syllabuses and examination requirements.

Early on it was decided that nuclear technology programme should constitute the 3rd year of a three-year Bachelor's program. For students to be admitted to the programme they must have completed at least two years of studies on a Bachelor's programme in mechanical or electrical engineering at a Swedish university. The motivation for this is twofold. Students can be recruited to the programme from universities close to the nuclear power plant operators, which is expected to increase the chance of them taking up employments at the local nuclear power plants. Also as previously noted, the demand from industry is not for engineers specialized in nuclear engineering, but rather mechanical and electrical engineers with a solid knowledge in nuclear technology.

When students have been admitted to the programme they undergo security and medical checks required by the nuclear regulatory authority, i.e. the Swedish Radiation Safety Authority, for employment at a NPP. This serves two purposes. First the situation where a student who has completed his/hers education is denied employment on formal grounds can be avoided. Second, the students having obtained security and medical clearances can easily obtain access to Swedish nuclear power facilities for study visits and Diploma works.

4.2 Programme syllabus

The educational programme has been developed with the objective of providing the students with a solid foundation in non-site specific nuclear technology (Fig. 1). The programme syllabus was developed with the assistance of KSU in order to ascertain that it, as far as possible, fulfils the need of the the NPP operators. When employed, new staff will then enter on-the-job education and training programs that are site and task specific.

Programme Syllabus
Introduction to nuclear engineering
Reactor physics
Thermal hydraulics and steam turbine technology
Light water reactor technology
Chemistry, materials and fuels for reactor applications
Nuclear power safety
Electrical power engineering
Nuclear power operation
Future nuclear energy systems
Degree project in nuclear power technology

Fig 1. Programme syllabus for the one-year programme. With the exception of the degree project which is 15 ECTS all other course modules are 5 ECTS.

All courses have been developed from the ground up by teachers from the Division of applied nuclear physics working together in order to make sure that there is a progression between courses and that they link to each other without unnecessary repetition. Constructive alignment between course goals, examination and teaching has been of great importance when designing the courses. The course syllabuses have been designed in accordance with the Bologna model meaning that the course goals are possible to quantify and verify.

While the bulk of teaching is provided by teachers/researchers from UU, extensive use is made of specialists from industry and authorities for teaching different subjects unique to the nuclear industry, e.g. nuclear power operations, project management and nuclear legislation.

One rather unique aspect from the Swedish perspective is an extensive mentoring programme that has been established in collaboration with the Swedish chapter of Women in Nuclear™ (WiN). Each student regardless of gender is assigned a female personal mentor who is working in the nuclear industry. During the course of the education six mentoring seminars are arranged where all students and all mentors meet. In between seminars mentors and students arrange face to face meetings on an individual basis.

Study visits and laboratory exercises are of great importance in any engineering education programme. For this reason industry puts several of their specialized facilities at the disposal of the programme that would otherwise be inaccessible for undergraduate education. A notable example is the Barsebäck nuclear power plant that has been shut down, and at present is operated by KSU as a training facility for nuclear power plant staff and contractors. Students spend a full week at this NPP as part of the *Light water reactor technology* course in order to familiarize themselves with the different systems of a LWR and how they interact. In addition student spend several days at KSU's full-scale reactor simulator facility in Studsvik to acquaint themselves with the control room environment and perform laboratory exercises concerning different aspects of reactor physics and reactor operation procedures. As part of the *Reactor physics* course, laboratory exercises are performed at VTT's TRIGA reactor facility in Helsingfors, Finland.

4.3 Recruitment and marketing

When developing the Bachelor's programme in nuclear technology, one important aspect was that students from different Bachelor's programs in mechanical and electrical engineering should be admitted. In order to determine which Swedish Bachelor's programmes provided the students with the right background knowledge to follow the nuclear technology programme a study was made. As a result of the study it became obvious that most Bachelor's students in mechanical engineering did not have the required prior knowledge to take the course in E*lectrical power engineering*. Conversely, most Bachelor's students in electrical engineering did not have the required prior knowledge to take the course T*hermal hydraulics and turbine technology*. In order to resolve this problem it was decided that in parallel with the course *Introduction to nuclear power* students are required to take participate in one of two short courses in either *Thermodynamics* or *Electrical systems* depending on their prior knowledge.

Marketing of the programme requires considerable effort. First and foremost because the programme is aimed at students that are already inside the higher educational system and consequently are not searching for an alternative educational path. Second, even though Swedish students' interest in nuclear technology can be considered high, it does not necessarily imply that one is prepared to embark on a career with in nuclear technology. In To promote the programme, in addition to the usual marketing lunch seminars are held at regional universities with representatives from both UU and the nuclear industry. Participation in career fairs organised by student organisations around the country is also an important part of the marketing.

5. Concluding remarks

The UU nuclear technology education strategy has proved very successful. Starting from essentially zero in 2003, presently UU is by far the largest provider of contract education to professionals within the Swedish nuclear industry. In order to resolve present and future recruitment needs of industry, UU has successfully launched a bachelor's programme in nuclear engineering in close collaboration with the nuclear industry. For the first year 81 students applied for the Bachelors's programme, 48 of the applicants fulfilled the prerequisites and 25 students were finally admitted to the programme. At the time of writing the 23 students remains within the programme and are expected to graduate in June 2011.

The Bachelor's programme as developed in Uppsala may serve as a template for deeper integration of authority and industry into the academic teaching, and for a larger involvement of academic staff into industry and authority competence development

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THE TRAINING COURSE “EUR COURSE 2010”

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ABSTRACT

The paper deals with goals and a course of the training course „EUR COURSE 2010” which took place in Nuclear Research Institute Řež plc Conference Center in 13 -16 September 2010. Nuclear energy is one of the means the European utilities must consider to meet future electricity needs. Therefore the major European electricity generation companies which form the EUR (European Utility Requirements) organisation, together with the European Nuclear Education Network Association and the Technology Platform “Sustainable Energy for the Czech Republic”, organized a three-and-half-day course aimed at post-graduate students in nuclear engineering and young professionals.
The EUR technical specifications are requirements dedicated to the design of new reactors - GEN 3 reactors. The objective of the Course was to provide a basic view of the key requirements developed in EUR, information about the EUR comparison works with the other design specifications and hints about the background situation in Europe.
This Course was open to anybody with a minimum scientific background. It was intended to provide first hand information to young professionals and post-graduate students who are considering a career in NPP R&D, engineering or operation or to young engineers that have already started a career. The lecturers were experienced engineers or managers from major European utilities involved in a nuclear generation or support activities.
This Course was also a good opportunity to develop contacts between the participants.

1. Introduction

Education and training of the young European professionals in nuclear has been one of the important tasks the EUR organization has carried out for several years. In June 2005, the EUR utilities organized a one-week course on Gen 3 LWR technology for young professionals and students in Helsinki (1). The course consisted from two parts:

- Part 1: insights on the EUR document (History and evolution, Key technical features: safety & operational performance)
- Part 2: the playing ground and the other players in Europe (the vendors and their main Gen 3 LWR designs: Areva, Westinghouse and AEP Moscow)

The course attracted around 50 participants and was assessed very positively, so that the EUR organization received numerous requests to organize new sessions. After a long discussion period, agreements were settled in 2009 with European Nuclear Education Network (ENEN), and World Nuclear University (WNU) to organize new courses. Two rather complementary proposals were put on the table and it was proposed to split the former EUR course into two parts:

1. An one-week course organized by WNU that would focus on the regulatory and political backgrounds, the autor's parts and the main standardized Gen 3 products available. A

first session of this WNU Forum on Harmonization of Reactor Design Requirements was organized by WNU in September 2009 in Manchester. It proved very successful.

2. An one-week course organized by ENEN that would be more technical and describe the EUR requirements more in detail, the regulatory requirements as well as the standardized Gen 3 products proposed in Europe.

There was a will to organise the second one relying on ENEN and local organisers support for logistics.

Fig. 1 The current member-utilities of the EUR organization

1.2 The EUR document

For reasons such as diversity of supply, evolution of the costs of alternative energies, new uses of electricity, the major European electricity producers have decided to keep the nuclear option open, to had the ability to build new nuclear plants if their interest or a necessity would request it. Several of them are today engaged in tendering or building. Most of the utilities have been inclined to pre-select Gen 3 LWR's technology that builds upon the successful feedback of experience of the operating fleets in Europe. Producing a common technical specification for safety and performance, the European Utility Requirement (EUR) document that sets out harmonized design targets has been one of the joint achievements of the European utilities (1). On this base the main vendors have developed (and still are) standard Gen 3 LWR designs adapted to the European market that could be licensed for construction in all the countries without major design changes.

Fig. 2 Printed version of the EUR document

The EUR document is structured in four volumes:

- Volume 1 (Main policies and objectives) defines the major design objectives and presents the main policies that are implemented throughout the EUR document.
- Volume 2 (Generic nuclear island requirements) contains all the generic requirements and preferences of the EUR utilities for the nuclear island.

- Volume 3 (Application of EUR to specific designs) is divided into a number of subsets. Each subset is dedicated to a specific design that is of interest to the participating utilities. A subset includes a description of the design and an analysis of compliance vs. the generic requirements of Volume 2. It may also include design dependent requirements.
- Volume 4 (Power generation plant requirements) contains the generic requirements related to the power generation plant.

2. The Course organization

The "EUR COURSE 2010" has been organized from 13th to 16th of September 2010 in Husinec-Řež near Prague, the Czech Republic and was attended with 98 participants from 19 countries (Bulgaria, France, Germany, Sweden, the Czech Republic, Russian Federation, Slovakia, Slovenia, Hungary, Japan, Belgium, Poland, Greece, Italy, Lithuania, Finland, Tunisia, the UK, Netherlands), mostly the young generation. Presentation were lectured by 14 experienced engineers or managers from 8 major European utilities – members of EUR organization (E.ON, EDF, Enel, CEZ, Swissnuclear, Tractebel, TVO, Vattenfall) involved in a nuclear generation or support activities.
No less important part of the Course was two social events. These events supported possibility to develop contacts between the participants. During Prague City sightseeing on board of a historical tram or during the Vltava river cruise with a dinner, young experts had opportunity to establish and develop good personal and profession contacts which can be useful in their future professional careers.

Fig 3. Audience of the "EUR Course 2010"

This Course was co-organised by the EUR Organisation and the ENEN Association, in close cooperation with the Technology Platform "Sustainable Energy for the Czech Republic" , the Nuclear Research Institute Rez plc, and the Czech Technical University in Prague. The feedback from the Course has been very positive.

3. Objectives of the Course

The Course targeted public were young professionals and post-graduate students undertaking a career in nuclear. The Course served also as good information source for skilled engineers looking for detailed information about EUR and for students considering a career in the nuclear in Europe. The Course was practically opened to anybody who had a minimum scientific background and wanted to learn first hand information from experienced engineers from major European utilities.

Fig. 4 Discussion during the "EUR Course 2010"

The main objectives of the Course were to provide:

3.1 Relation with background evolution in Europe and worldwide

Participants were informed about Gen 3 projects that are developed in world, especially for Europe (AP1000, EPR, EU-APWR, AES 2006, ATMEA, KERENA) and about the process of standardisation of nuclear plant design and harmonisation of safety standards for nuclear plants to simplify and facilitate licensing and construction process in any of European countries.

Day 1	Day 2	Day 3	Day 4
Introduction to EUR document	General safety approach 1	Design process	Comparison EUR – URD
Projects developed for Europe	General safety approach 2	Mechanical systems & components	Comparison EUR – WENRA
Standardisation and harmonisation	Containment & severe accident 1	Grid requirements & electrical systems	Discussion and summary
Design basis 1	Containment & severe accident 2	I&C and man-machine interface 1	
Design basis 2	Plant performance & operation	I&C and man-machine interface 2	
		Core & fuel design	

Tab 1: The Course program

3.2 Detailed view of the key Gen 3 requirements developed in EUR

The objective of this Course part was to give a basic orientation in a generic Gen 3 Light Water Reactor (LWR) specification written by investors and nuclear power plant operators with wide experience basis (6 different vendors and 19 operators in Europe). These requirements formulated as open design objectives and functional requirements fitting all the designs of interest of the European utilities were presented in following sections: Design basis, General safety approach, Containment & severe accident, Plant performance &

operation, Design process, Mechanical systems & components, Grid requirements & electrical systems, I&C and man-machine interface and Core & fuel design.

The aim was to permit Course participants to understand principles and the logic of the EUR technical requirements formulation, which is neutral to any specific design.

3. 3 Information about the comparison works with the other design specifications

Topical base information about latest EUR activities deal with a frame comparison of EUR requirements with the EPRI Utilitity Requirements Document (URD) and a comparison of EUR requirements with requirements of the Western European Nuclear Regulators' Association (WENRA) for existing nuclear plants were presented.

Fig 5. Chairman of the EUR as a speaker of "EUR Course 2010"

4. Conclusion

The EUR organization is one of the key player for European nuclear new built in the interaction with stake holders. The EUR organization contribute to the European Union nuclear safety harmonization as well as to the nuclear power plant project standardization for a harmonious development of well balanced energy sector with the use of Gen 3 state-of-the-art nuclear power plants. The EUR generic technical specifications are fully operational and may be used by utilities or other bodies. Therefore the EUR organization with cooperation with other involves stakeholders decided to organise this Course with the aim to give first hand information about the EUR requirements to young professionals an to everybody looking for detailed information about EUR requirements. The positive evaluation of the Course by participants warrants to state that the goals of the Course were successfully met.

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TRIGA® Reactors

An Excellent Tool for Training and Education

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General Atomics

Abstract

Education and training are important elements for the future of nuclear science, technology and safety. Fields of interest include high-technology applications in nuclear techniques and neutron sources, advances in the areas of power reactor safety, establishing the scientific basis of new reactors, training of personnel needed to operate, maintain, regulate and improve reactors or other facilities associated with nuclear power. Also, creating a knowledgeable public through education usually means less opposition and more support. Education and training for safeguards, operators, researchers and quality programmes (calibration services, etc.) are one of the main utilisations of TRIGA research reactors. Use of a reactor as a training tool for university students studying nuclear engineering and/or physics, where there is a growing demand at European Universities, is of vital importance. Several TRIGA Reactors in Europa such as the TRIGA Mainz, the TRIGA Vienna or TRIGA reactors in Italy and Slovenia offer a broad range of nuclear-related courses for training and education. This paper concentrates especially on education and training at the TRIGA reactors in Mainz and Vienna.

Introduction

Research and training reactors deliver important elements in nuclear science technology, education, training and research infrastructures. Training of personnel is needed to operate, maintain, regulate and improve reactors and other facilities associated with nuclear power activities, and to manage and direct nuclear technology's development and nuclear science research. The basis for advances in power reactor safety is well-educated scientists and engineers. Development of high-technology applications in fields such as materials science, fluid dynamics and biomedical science, where neutron sources are needed, can profit through utilisation of research reactors. Due to the dismantling of power and research reactors, radiation protection and knowledge in the handling of radioactivity material becomes even more important. International training courses are important to harmonize the knowledge and establish cooperations between research reactors in various regions [1].

Due to a decreasing number of students taking nuclear subjects in recent years, the lack of young nuclear scientists, technicians and engineers to replace retiring staff and ageing research reactor facilities being closed and often not replaced education and training becoming more important. On the other hand, the future of TRIGA reactors which offer excellent training and education possibilities is becoming more and more unsure, especially, as announced recently, there could be a loss in the supply of TRIGA fuel in the coming years.

There exist a large number of publications on TRIGA type reactors, therefore no detailed description of the training and educational reactor is given here [2,3].

A broad spectrum of scientific research and commercial applications are carried out both in Mainz and Vienna [4,5]. For education and training, various courses in the nuclear field and in radiochemistry, in radiation protection, in reactor operation and physics are held for scientists, advanced students, teachers, engineers, technicians and international customers.

Reactor operation and reactor physics

Several TRIGA reactors offer coursesconsisting of lectures in reactor physics and practical training in reactor operation at steady state power and in the pulse mode. The course focuses on the understanding of the general behaviour of a nuclear reactor and the main objective is to introduce the basics of reactor operation, reactor techniques and physics in practical examples at a research reactor. The participants receive practical experience in operation of a nuclear reactor. The main part of the course includes:

- daily and monthly inspections at the reactor,
- operation of the reactor in the steady state mode,
- reactor pulses with different reactivity insertion,
- neutron flux measurements at different irradiation positions,
- the influence of test samples, such as Cd, to the reactor operation,
- void coefficient
- power calibration
- temperature coefficients
- calibration of the control rods,
- fuel inspections,
- function and sensitivity of the compensated ion chamber,
- reactivity measurements and
- error diagnostics.

A complete course may last from one to two weeks with a maximum number of 6 to 10 participants to assure an optimal mentoring. The requirements for participation on the reactor operation and reactor physics courses are basic theoretical knowledge in nuclear physics, nuclear reactions, fission reactions, production of neutrons, cross sections, chain reaction, moderation, critical size, neutron life cycle and reactor design. The students should have had lessons in either Nuclear Chemistry or Reactor physics and kinetics. Every participant receives a textbook on the theoretical background, the requirements for the experiments, the experimental procedures, tables for measured values and a description for the analysis and reporting. The courses are available in English or German language.

One of the unique experiments at TRIGA type reactors is “the reactor pulses with different reactivity insertion”, which can be carried out at TRIGA reactors. Due to the unique characteristics of the Zr-H moderator used in TRIGA fuel, one can withdraw a control rod completely and suddenly from the critical core. Any other reactor would be severely damaged by this operation, which can be performed routinely at the TRIGA and results in a power pulse or power burst. The property of the Zr-H moderator that makes this possible is that the H-atoms form oscillations around its lattice position. The energy of these oscillations is quantified similarly to a three-dimensional harmonic oscillator (Einstein oscillator). Incident neutrons are moderated and are then in thermal equilibrium with these atoms. During a power burst, the fuel temperature rises and therefore, the population at higher oscillation energy levels of the moderator atoms increases, thus reducing the moderating effect of the neutrons. The neutrons may even be accelerated by the collisions with the H-atoms and the thermal neutron spectrum is hardened. Therefore, the number of fissions and the reactor power is decreased. The whole procedure takes about 3 ms while the peak power increases to 250 MW, and the pulse width (FWHM) is about 30 ms under these conditions [5].In this experiment the reactor is put in low power critical state, out of this state a pneumatic absorber rod is ejected from core which puts the reactor into a prompt critical state. This power excursion is reversed by the strong negative temperature coefficient of the U-Zr-H fuel.

Nuclear Chemistry I

In addition to the course“Reactor operation and reactor physics”, a course “Nuclear Chemistry I”, is carried out at the Institute of Nuclear Chemistry at the TRIGA Mainz.

The training course is focused on students of chemistry and physics of the 7th semester. It is executed 4 times a year. Each course is two weeks, for a maximum of 18 participants. The course teaches the basics of nuclear chemistry, nuclear physics and radiation protection, as well as the handling of radioactive material, radiochemical preparations and analysis, and the technology to detect radioactive irradiation. Requirements for participation on the course are a certificate of successful attendanceat the lecture “Introduction of Nuclear Chemistry” [5]. Each day has its own subject:

- production and measurement of radioactive isotopes produced at the reactor,
- decay and production of isotopes, balance of mother – daughter isotopes,
- the alpha decay,
- the biological effect of radiation and radiation protection,
- experiments for gamma radiation, gamma-spectroscopy,
- beta-decay, utilisation of semiconductor detectors,
- nuclear reactions with neutrons,
- nuclear fission,
- utilisation of radioisotopes, and
- trans uranium – the chemistry of neptunium (element 93)

Nuclear Chemistry II

This training course is focussed on research and takes 4 weeks. The participants work in the research groups of the institute under the guidance of a PhD student. The offered subjects depend on the actual situation of the institute.

A course in the NAA has the aim to demonstrate the capabilities of this method for trace analysis of various materials. At the moment, the NAA at the TRIGA Mainz is focused to determine trace elements in different materials belonging to projects in archaeometry, forensics and semiconductors for photovoltaic. The beam ports and the thermal column of the TRIGA Mainz are used for special basic and applied research in medicine, biology, chemistry and physics. Experiments are in preparation to determine the fundamental neutron properties with very high precision using ultra cold neutrons (UCN) produced at the tangential beam port. A second source is under development at the radial piercing beam port. Another experiment under development is the determination of ground-state properties of radioactive nuclei with very high precision using a penning trap and collinear laser spectroscopy. For many years fast chemical separation procedures combining a gas-jet transport system installed in one beam tube with either continuous or discontinuous chemical separation are carried out. In addition the thermal column of the reactor is also used for medical, pharmaceutical and biological experiments.The project is focussed on brain tumours and liver malignancies.Also cell cultures are irradiated in the thermal column at different neuron fluxes and detector systems are being tested in various applications. All these experiments are part of 4-weeks training course in Nuclear Chemistry II [6].

Radiation Protection

Education and training courses in radiation protection are offered for technicians, teachers, students and the fire brigade. Every year courses to receive knowledge in radiation protection are carried out following the requirements of the German Radiation Protection Decree. The experimental programme includes measurements of the neutron- and γ-dose rates at the biological shield and at the near-surface reactor pool. The reactor is operated at different power levels from a few Watts to 100 kW_{th} with dose rate monitoring as a function of reactor power.

For the education and training of students at school, teachers and young scientists, the TRIGA Mainz is working together with the German-Swiss Association of Radiation Protection. Different support programmes are held to advance the knowledge of the young generation and to motivate them to undertake tasks in radiation protection and nuclear field activities [7]. Similar Courses are carried out at the TRIGA Vienna where recently several pupils- and teacher's days have been carried out. At these courses the participants spent one day at the Atominstitut Vienna and carry out selected experiments which include TRIGA reactor start up and identification of various radiation emitters. The courses proved to be very successful and contribute a lot to better understanding of nuclear issues.

International Training Courses [8]

Eugene Wigner Course

The Eugene Wigner Course was established in 2005 in cooperation between the TU Bratislava, TU Budapest, TU Prague and the VUT. A group of about 15 students was subdivided into four groups, started all together in Bratislava and then rotated among the involved Technical universities. At this course they carried out practical work at three different research reactors including theoretical lectures, and a final examination which was accredited by their home university with 6 ECTS. During the last two years, financing of this course became very difficult and the course was stopped although the feedback from all participants was very positive.

Training Course for the MTR+3I EU project

The Atominstitut took part in the above mentioned EU project together with about 25 other European research centres. The contribution of the Atominstitut was to prepare a practical demonstration training course for future reactor operators. This course took place in March 2009 with five international participants and was successfully accepted as a demo course by the EU.

Nuclear Technology Education Consortium NTEC, UK

In 2007, the NTEC coordinated by the University of Manchester contacted the Atominstitut if it could offer a one week academic reactor course for NTEC students. The contract was signed and since this time totally six courses (two per year) were carried out, each course with six NTEC students. The course is credited by NTEC with six ECTS.

NPP Staff from Slovakia

Since several years, the Technical University of Bratislava is involved in the re-training of the NPP; staff of the NPP Bohunice and Mochovce. Since Slovakia does not operate a research reactor and Bratislava is very close to Vienna, the Atominstitut was asked to take over the practical part of the training course which has been performed six times since 2002.

MOL Courses

The Belgian research centre MOL is requested by the regulatory body to offer a re-training programme for their operators. In view of this task, the Atominstitut was asked to host totally 36 operators divided into six groups of six participants each to perform a course using experiments both from the standard reactor physics and kinetics course as well as from the reactor instrumentation and control course.

IAEA Junior Safeguards Traineeship Program

The IAEA recruits in regular intervals new safeguards inspectors, however developing countries complained that they do not have the prerequisites to apply for this job. Therefore the IAEA initiated as far back as 1984 every two years a 9 month training course for about 6 technicians from developing countries which are then in a position to apply for a job as safeguards inspector. The first practical part of this course takes place at the Atominstitut for one month every two years. In total about 120 junior safeguards trainees have passed through the Atominstitut.

Eastern European Research Reactor Coalition (EERRI)

In 2008, the IAEA initiated several research reactor coalition programs to increase cooperation and utilization of research reactors in various regions. One region is Central and Eastern Europe and therefore the Eastern European Research Reactor Initiative (EERRI) was created. The Atominstitut is part of this coalition and one target of this initiative is to offer practical training to young professionals. Since the formation of EERRI two such courses were carried out, the first course coordinated by the Atominstitut in cooperation with the Institute Josef Stefan in Ljubljana/Slovenia, the KFKI and Technical University in Budapest/Hungary, the second course was coordinated by the TU Prague in cooperation with the Atominstitut and the Institute Josef Stefan in Ljubljana/Slovenia. More courses are planned for 2011. Participants came through IAEA Technical Cooperation projects from all over the world.

Selected Courses for IAEA Technical Cooperation projects

The Atominstitut hosts IAEA fellows for periods of one month to one year through IAEA Technical Cooperation projects. Since 1983, more then 200 fellows participated at highly specialised training project from all over the world, the fellows are attached according to their interest to one of the working groups. Experience shows that after their return to their home institute long term relation and cooperation between the two institutes result as a positive outcome from these fellowships.

Summary

It has been shown that small university research reactorssuch as in Mainz or Vienna can be effectively used not only for standard training courseswithin the academic field but they can also be used commercially efficient by offering the education and training experience to other groups as mentioned above.

TRIGA reactors are a very important tool to train both future nuclear personnel (such asengineers, technicians, teachers, researchers) and especially university students. They provide very useful training to students or researchers in many nuclear fields and are a powerful tool for the advancement of other academic disciplines.

The training of nuclear personnel, as conducted currently in many TRIGA facilities,is an important contribution not only to the peaceful use of nuclear technologies but to worldwide nuclear safety in general. More significantly, the education and training programmes of TRIGA reactors can have a long term,substantialand sustainable effect on today's nuclear situation.

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WESTINGHOUSE GLOBAL TRAINING SOLUTIONS

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ABSTRACT

Westinghouse Electric Company provides fuel, services, technology, plant design, and equipment for the commercial nuclear electric power industry. Over the past 40 years, Westinghouse adult educational specialists and subject matter experts and have worked with the nuclear industry to provide training in these areas. During that time, Westinghouse evolved from simply providing training services to developing customer relationships that have become an integral part of the global industry's training solutions.

The evolution of Westinghouse training over the past decade was driven by the need to address individual learning capabilities in order to obtain a higher level of knowledge transfer and performance improvement, both of which are necessary to achieve increased plant safety and positive impact on business. The result is Westinghouse's **NucLearning**SM educational model. The **NucLearning**SM educational model is based on three corner stones: Relationships developed through long-term partnerships, the use of student-centred, blended learning techniques, and a focus on integrated plant operations in all training programs.

Application of a performance-driven training approach has led to significant improvements in training effectiveness, equipment reliability and maintenance, and has delivered improved financial performance for both Westinghouse and its customer organizations. A major part of this success is derived from building long-term partnerships around the use of online learning and advanced learning technology to present operations, engineering and instrumentation and control training programs on a global scale. Proven successes have also allowed Westinghouse to provide leadership and advice to other corporate industries as they prepare to meet their future learning needs.

Westinghouse has also extended the **NucLearning**SM concept into partnerships with colleges and universities to support the development of the industry's future work force pipeline for technicians, engineers and future management candidates. As an example, the training staff has been able to provide leadership to the education community through consulting and teaching courses in the University of Pittsburgh's Masters-level Nuclear Engineering Certificate Program.

Westinghouse is a positive influence on the direction the nuclear industry is taking with respect to training and learning. With the nuclear renaissance upon us, Westinghouse is uniquely positioned to work on a global scale to facilitate the production of well designed, well facilitated training programs that will prepare the industry to meet future demands of energy production and the resource challenges that accompany it.

1. Introduction

Westinghouse Electric Company, a group company of Toshiba Corporation, provides the technology that is the basis for more than 40 per cent of the world's operating nuclear plants, including 60 per cent of those in the United States. Over the past 40 years, Westinghouse

Proceedings of the Conference NESTet 2011, Prague, Czech Republic, May 15-18, 2011.

adult educational specialists and subject matter experts have provided training in fuel, services, technology, plant design, and equipment to utility and industrial customers in the worldwide commercial nuclear electric power industry. Its concern for the nuclear industry, its plants and its people allows Westinghouse to leverage learning for global success by developing relationships that allow a better understanding of utility cultures which, in turn, results in nuclear safety and performance improvement.

This paper provides an insight as to how Westinghouse works in partnership with utilities and the academic community to provide global pressurized water reactor (PWR) and boiling water reactor (BWR) training solutions to enable knowledge transfer and learning in this growing and exciting industry.

2. Westinghouse Training History

Westinghouse has offered nuclear training services since the early 1960's from its facilities in the areas surrounding Pittsburgh, Pennsylvania, USA. In 1971, Westinghouse formed a joint venture with Commonwealth Edison Company and established the Westinghouse Nuclear Training Centre in Zion, Illinois, USA. This training centre offered complete programs in initial license operator training. The curricula included a nuclear engineering principles program that included operations on a low power training reactor.

During this same time, Westinghouse Training in Pittsburgh developed specialty programs for engineers, comprehensive training for instrumentation and control technicians and engineers, plant specific programs for licensed reactor operators and senior reactor operators, and support services for utilities that conducted their own training. Training in fuels engineering was provided from both the Pittsburgh area and the fuel manufacturing facility in Columbia, South Carolina, USA.

Following the event at Three Mile Island in 1979, U.S. domestic utilities re-evaluated their training and qualification processes. As a designer and supplier of nuclear steam supply systems and experts in training system design, Westinghouse collaborated with the utilities to help them develop site-specific training programs in accordance with the systematic approach to training while considering lessons learned from Three Mile Island and current industry best practices. As the utilities expanded their training departments and developed their own site-specific training programs, Westinghouse's operations training portfolio shifted from a centralized function to utility-based training support, prompting Westinghouse to close its training facility in Zion, Illinois in 1991. Westinghouse has also provided training services for boiling water reactor (BWR) plants since 1980. In 2009, Westinghouse opened its U.S. Boiling Water Reactor Service Centre in Chattanooga. Tennessee, USA, where training programs combine formal classroom instruction with hands-on laboratory exercises to maximize student learning and skills development.

Passing through changes in ownership between 1997 and 2006, Westinghouse achieved significant growth that resulted in establishing offices in thirty locations throughout the world by 2010, as shown in Figure 1. With the nuclear renaissance a reality, Westinghouse Training expanded to also support the development of plant staffs for the new nuclear plants currently under construction, and those being planned.

Fig 1. Westinghouse Global Locations

Westinghouse global regionalisation provides a training presence in Europe that allows local resources to build the relationships necessary to achieve alignment of cultural expectations, a better understanding of training needs and, therefore, be in a position to leverage global Westinghouse resources to assist nuclear utilities in achieving safety and performance improvement goals as well as positive impact on business performance.

3. The *NucLearning*SM Educational Model

In the late 1990's, Westinghouse began to re-evaluate its traditional training methods and, in 2001, launched its first collaborative, interactive, online course. Over the years, several additional online courses were developed to allow instructors to address individual learning capabilities. This learning method leads to a higher level of knowledge transfer and performance improvement, both of which are necessary to achieve increased plant safety and performance, and positive impact on business. For those courses taught in the classroom, curricula have been converted to a student-centred format which puts the student in the centre of the learning process, thus making him or her an active participant in the learning process.

The transformation of Westinghouse training methodology to a progressive, collaborative, blended learning format has resulted in a proven training philosophy called the **NucLearning**SM educational model. The model is based on three corner stones: Relationships developed through long-term partnerships, the use of student-centred, blended learning techniques, and a focus on integrated plant operations in all training programs.

3.1 Long-Term Partnerships

Westinghouse recognizes that the safe operation of a nuclear power generating facility strongly depends on the knowledge and skills of the nuclear professionals who operate and maintain the plant. Higher level knowledge and skills in the technical, maintenance and engineering disciplines are most effectively provided by the subject matter experts and educational specialists of Nuclear Steam Supply System (NSSS) suppliers, especially when

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utility resources are strained at a time when knowledge transfer needs have never been so critical. In order to facilitate this knowledge transfer, Westinghouse has established close working relationships with utilities that have resulted in the alignment of cultural expectations, a better understanding of training needs and, therefore, a good knowledge of performance improvement goals.

To execute this relationship-centred model, a project manager is assigned to lead integration activities and project execution. Supported by the Westinghouse training team, the project manager works closely with the utility staff to fully understand expectations and assist in identifying performance objectives and training development needs. This interaction enables selection of the most appropriate blended learning solutions that will result in knowledge transfer and positive impact on business performance. The project manager, in turn, mentors the Westinghouse staff and subject matter experts on contract requirements, utility expectations, and performance and business impact objectives. This relationship allows Westinghouse to be a part of the utility's performance improvement initiatives rather than being perceived as simply a provider of training services.

3.2 Blended Learning Techniques

Application of a performance-driven training approach has led to significant improvements in training effectiveness, plant equipment reliability and maintenance, and has delivered improved financial performance for both Westinghouse and its customer organizations. A major part of this success is derived from building long-term partnerships around the use of online learning and advanced learning technology to present operations, engineering and instrumentation and control training programs on a global scale.

Westinghouse is proud to note that its learning platform provider, Blackboard®, wrote a case study on the Westinghouse application of its product as a model for other companies and industries to follow. [1] This case study appeared in the November issue of Training and Development Magazine. Blackboard® also published a white paper on the importance of measuring Impact on Business™ (IOB™) of training, and not simply looking at Return on Investment (ROI.) [2] The white paper references the IOB™ that is being achieved with online learning by the pharmaceutical industry, the health care industry, and the nuclear industry as the result of the last decade of work and research in online learning. [3]

According to Bersin & Associates, "Westinghouse's online programs include the thoughtful blend of formal and social, instructor-facilitated online learning activities, spaced over time, that is common in the academic world, but less so in corporate training. It makes sense, given the sheer amount and complexity of knowledge and skills they must transfer to their students, that their program would resemble a school – a very effective and well-run school at that." [4]

3.3 Integrated Plant Focus

Educating the future workforce poses unique challenges due to the complexity of nuclear power plant technology. "Having limited prior knowledge of nuclear power plants, and thus no contextual reference, students can have great difficulty appreciating the practical applicability of what may appear to be very academic concepts." [5] Westinghouse acknowledges that integrated plant knowledge and its application are essential parts of learning success, long-term retention, and performance improvement. An on-going effort is in place to provide Westinghouse instrumentation and control instructors the opportunity to achieve senior reactor operator (SRO) certification. In cases where this has already been achieved, the use of instructors with integrated plant operational knowledge has resulted in plant technicians being able to assimilate this knowledge to solve complex troubleshooting problems in a safe and timely manner. Plant technicians are able to appreciate the consequences of their actions on plant operations, thereby reducing human errors.

In operational programs such as introduction to nuclear plant operations and senior reactor operator certification training, the traditional sequence of presenting theoretical fundamentals prior to plant systems has been replaced with the application of theoretical principles in an integrated fashion with plant systems. Theoretical concepts are now more relevant to the students, and program results have shown that students achieve a greater ability to analyse and synthesize information during advanced phases of training and on the job following program completion.

4. Application of the *NucLearning*SM Educational Model

Westinghouse will continue to be a positive influence on the direction the nuclear industry is taking with respect to training and learning. The goal is to lead and to work with the global nuclear industry to facilitate the production of well designed, well facilitated learning programs that will prepare the industry to meet the future demands of energy production.

Proven successes have allowed Westinghouse to provide leadership and advice to other corporate industries, such as the pharmaceutical industry, as they prepare to meet their future learning needs. [3] Westinghouse also extended the **NucLearning**SM educational model to partnerships with colleges and universities to support the development of the industry's future work force pipeline for technicians, engineers and future management candidates. Examples of this include: Consulting and teaching courses in the University of Pittsburgh's Master's level Nuclear Engineering Certificate Program; curriculum support for Chattanooga State College for non-destructive examination (NDE), quality assurance (QA), and quality control (QC); and support for grant submittal in partnership with Indian River State College and NextEra Energy, Inc. for incorporating scalable nuclear plant simulation into college curricula.

5. Summary

Westinghouse offers nuclear technology and engineering training programs to the global nuclear industry through both traditional and online courses that incorporate advanced educational techniques that are tailored specifically to the needs of utility personnel in order to achieve competency-based learning objectives. With the nuclear renaissance upon us, Westinghouse is uniquely positioned to work on a global scale to facilitate the production and implementation of well designed, well facilitated training programs that will prepare the industry to meet future demands of energy production and the resource challenges that accompany it.

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WAYS TO SUCCEED THE HR CHALLENGE OF THE NUCLEAR RENAISSANCE VIA PRESERVATION AND EFFECTIVE MANAGEMENT OF NUCLEAR KOWLEDGE

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ABSTRACT

The crucial pre-condition of a successful implementation of the ongoing nuclear renaissance is a sufficient amount of proper educated and skilled workers in the area of nuclear safety for operation, design and maintenance. This paper will be focused on some ways directed towards the preservation and effective nuclear knowledge management in the area of reactor pressure steel studies. Results from the EC's Joint Research Centre project CAPTURE will be discussed in details. This is also a positive example of a fruitful collaboration of experts from European countries with experts from the former Soviet Union.

INTRODUCTION

In the last decade, preservation and optimal nuclear knowledge management are becoming a rising challenge worldwide. Many papers and experts talks at different conferences stressed attention on stagnating or decreasing expertise connecting to decreased numbers of graduates, professors or research workers. [1-3]. Several networks were created in the Europe in frame of the 5th , 6th or 7th Euratom Framework Programme accented international collaboration in training and education physics (EUPEN, STEPS) or in nuclear power engineering (ENEN, NEPTUNO or TRASNUSAFE) [4-6].

POSITIVE EXAMPLES

In the Central-European region, there exists a very extensive and also effective international collaboration in nuclear industry and education. Similarly good situation is also among universities and technical high schools in this area. Actually, the Slovak University of Technology in Bratislava has established contacts with many universities abroad in the area of utilization of research and training reactors. One of good examples of international collaboration is ENEN – European Nuclear Education Network Association [7] which resulted in a formation of "Eugene Wigner Training Courses on Reactor Physics Experiments" [8, 9] running in the last years as a mutual effort of the Budapest University of Technology and Economics (Budapest, Hungary), Czech Technical University (Prague, Czech Republic), University of Technology (Vienna, Austria), and Slovak University of Technology in Bratislava (Bratislava, Slovakia). In total 69 participants from different European countries as Austria, Belgium, Bulgaria, Czech Republic, Finland, Italy, Israel, Romania, Slovakia, Slovenia, Sweden and Switzerland took part at these international training courses so far. In the frame of these courses, students of nuclear engineering visited three different experimental facilities located at the course organizers' institutes and carried out experimental laboratory practices. It is highly recommended to continue in this practical oriented course.

The preservation of nuclear knowledge is possible only via effective use of all tools (Fig.1).

The high level nuclear education is very important also due to permanent increasing of nuclear experts age. To replace some of them are not easy. Beside this, the nuclear community needs some internal dynamic, which is connected to the young people activities.

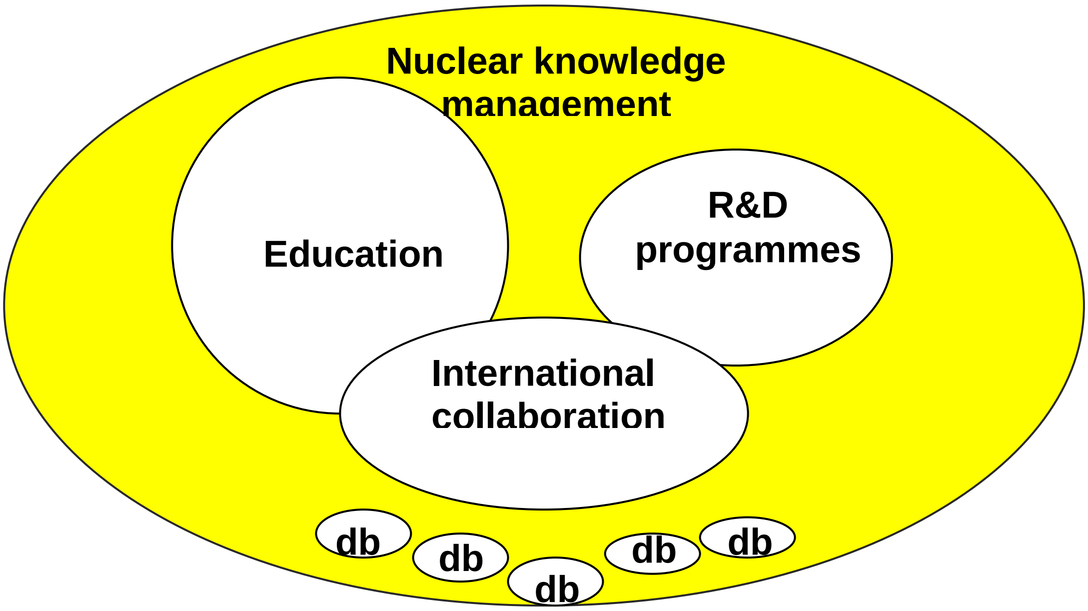

Figure 1. Example for VVER database.

The problem is that the amount of students taking these lectures is low. Proper education at the university is a source of knowledge and attitudes for the whole life. Theoretical and practical experiences, professional approach and consistency are very important also from the safety culture point of view. University lectures and seminars are basically opened for public and this academic field can be made better use of in public relations. It is an investment mainly to young generation. During discussions with students, teachers can form their professional orientation according to their abilities and needs. Good teacher encourages also the growth of student and shapes his personality. Graduated students have to learn to take responsibility for their decisions and their academic level of education.

Unfortunately, there was not real interest for educated nuclear engineers from industry till know. Although oral declaration how these graduates are necessary for NPP operators, in reality the nuclear industry does not attract young specialist. Fig. 2 shows that about 50 percent of graduates of specialized nuclear power engineering study at STU Bratislava went completely out from this area. Hopefully next years connected to the commissioning of Mochovce 3, 4 will change this approach.

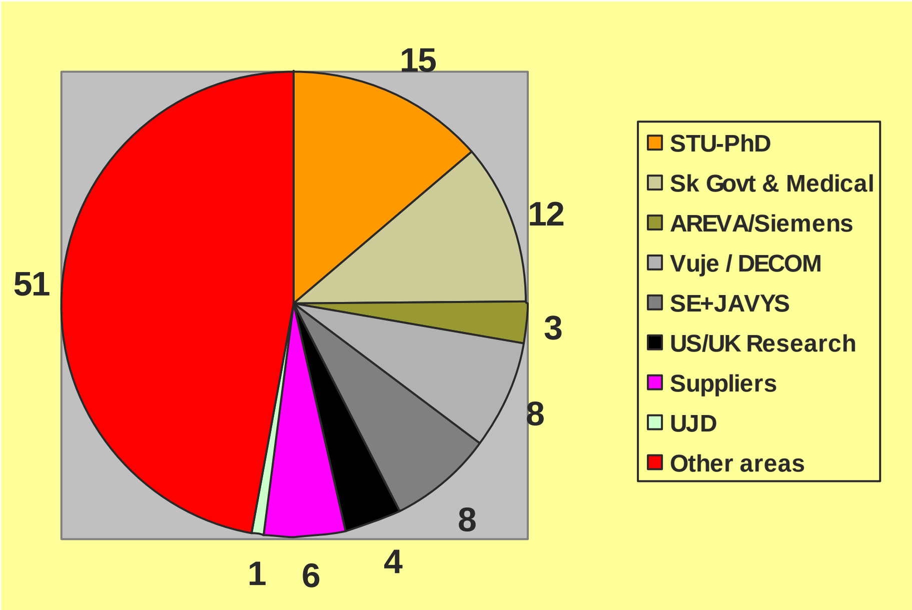

Figure 2. Working addresses of STU graduates in nuclear power engineering in last 12 years.

CONCLUSIONS

The actual status of education and training in nuclear power engineering is the real cause for concern. This education has to be based on the serious long term basis organised and guaranteed by high quality academic institution. It is a duty of educated and responsible people to highlight the necessity for a renaissance in nuclear education and training and recommend the following points:

- We must act now
- Strategic Role of Governments
- The Challenges of revitalising nuclear education
- Vigorous research and maintaining high quality training
- Benefits of Collaboration and Sharing Best Practices

I hope that it still not to late.

Acknowledgement

Financial contribution of the grant VEGA 1/0129/09 and project CAPTURE is acknowledged.

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TRAINING AND TUTORING OF PROFESSIONALS IN NUCLEAR SAFETY, NUCLEAR SECURITY AND RADIATION PROTECTION

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1. International perspective on nuclear safety training

In 2003, the International Nuclear Safety Advisory Group, INSAG, published its report number 16 [1] in which it addressed the risk for existing nuclear power programmes to not maintain knowledge, training and infrastructure for research and development in nuclear safety. Few years after, capacity building in nuclear safety, nuclear security and radiation protection was also seen as a major challenge in new and expending nuclear power programmes at a G8 dedicated workshop [2] and as a conclusion of an IAEA conference [3].

These reports and proceedings discussed capacity building as a whole and formal education in nuclear science and technology was seen as its important component. Certainly, nuclear installations integrate a wide range of scientific and technological disciplines, and nuclear and radiation safety requires highly professional expertise in broad areas of nuclear technology. However, the construction of expertise in nuclear safety is more than a matter of formal education as it involves transfer of non-formal knowledge, practical experience and culture. Although this is unchallenged, non-formal education in nuclear safety was only globally discussed at the last IAEA conference on the challenges faced by Technical Safety Organisations (TSO) in enhancing nuclear safety and security that took place in 2010. In the conference conclusions, it was recognized that the quality of training in safety and security assessment depends upon the practical expertise of the trainers [4]. This issue was further discussed at the last EUROSAFE conference through a workshop devoted to European cooperation in education on nuclear safety. It was again emphasized that safety training has to be implemented in educational planning through TSO-informed teaching programmes [5].

2. Training and tutoring needs and offers

The major part of the non-formal education received by European TSO staff comes from in-house training programmes. One of the concerns raised in European Commission fora was the possibility for some small safety organisations to deliver training to their staff without building their own training school. Recently, there were also repeated requests coming from newcomers in the nuclear energy field with still limited infrastructure to train their safety staff. In 2009, the European TSO Network, ETSON Association, commissioned a study to assess both training needs and offers for Europe and for expected new nuclear programmes elsewhere [6].

The assessment was based on a survey which was carried out from March to May 2009 and on public data which were gathered worldwide. The survey covered twenty three TSOs and Nuclear Regulatory Authorities from thirteen European nuclear countries, four countries planning a nuclear energy programme, and one non-European nuclear country, as well as the International Atomic Energy Agency, and the European Commission. The survey scope covered the demand for training, and the internal and external training schemes which are used by these organisations to train their staff.

Apart from large European TSOs, none of the existing nuclear safety training offers is supported by an important pool of experts and therefore the present offers remain quite static and basic. Contrary to training, there is almost no offer for tutoring at the international level. Some staff exchange may exist between nuclear safety organisations but this is limited to a few cases. Tutoring is mostly carried out internally. Although tutoring might be done continuously by older colleagues, the trainee requires some time before he/she can produce any added value for the organisation. This explains in particular why external tutoring is very limited and is usually the consequence of bilateral cooperation agreements. Another reason

is that the tutoring of foreign trainees is most of the time practically free of charge. It is felt that hosting foreign trainees is therefore representing an important investment impacting negatively productivity.
The study concluded that there would be an interest in pooling the large education efforts in which European TSOs are already involved within a single European training institute because it would represent a comprehensive commercial training offer. Candidate countries feel especially attracted because European TSOs benefit from a worldwide recognition. The study also evidenced gaps in the expert's level training and therefore needs to develop courses for specialists targeting already experienced safety engineers to favour knowledge and experience transfer. The studies made recommendations to open the training beyond the European borders and to envisage the possibility of locating courses according to the interest from a specific region or for a specific topic.

3. ENSTTI, a European TSO initiative

Considering the conclusion of the 2009 needs and offers assessment, the European TSO took in 2010 the initiative to create the European Nuclear Safety Training and Tutoring Institute, ENSTTI, in association with the European Union and the IAEA, to drive the vocational training of the present and coming generations of professionals in nuclear safety, nuclear security and radiation protection.
The main goal of ENSTTI is to train European TSOs' technical staff throughout their professional life in TSOs' state-of-the-art assessment methods and to raise the overall assessment technical level. Leverage of nuclear safety expertise and harmonization of assessment methods are goals beyond the European Nuclear Safety framework and ENSTTI opens its training activities to participants from nuclear safety organizations from other regions of the world.
ENSTTI offers short applied training sessions and longer tutoring periods both for young professionals and for those with some professional experience in the nuclear sector. All course programs include working groups, simulator sessions, technical visits and open discussions. The ENSTTI formation curriculum is made up of three parts: the "Induction to Nuclear Safety" course, where during a four-week course trainees approach the bases and culture of nuclear safety, nuclear security and radiation protection; tutoring periods where trainees are integrated into TSOs' operational units; and short training modules for specialists, where TSO experts and other safety specialists are briefed in-depth on a particular safety or security topic. Certificates are delivered at the end of training periods reflecting the knowledge acquired. During the tutoring periods customized to each applicant's future work, trainees work alongside an expert with safety responsibilities within its own organization. The content and duration of tutoring periods are adapted to the profile of each individual. The personalized support is continued through regular contacts with safety experts once the trainee returns to work.
ENSTTI relies primarily on its TSO Members to provide professors and facilities for the organisation of its activities, training sessions and tutoring fellowships. ENSTTI lecturers and trainers are all recognized experts in their technical domain. Trainees have the possibility of sharing their experience with top experts in nuclear safety, nuclear security and radiation protection.
Through its activities, ENSTTI contributes to the harmonization of nuclear safety and security practices and to the networking of today and future nuclear safety experts in Europe and beyond.

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Education and Training in Nuclear Physics, Nuclear Applications and Nuclear Engineering in Greece

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ABSTRACT

Though nuclear energy is not an option in Greece – at least for the near future – education, training and research in the fields of Nuclear Physics (NP), Nuclear Applications (NA) and Nuclear Engineering (NE) is well developed and has a long-standing tradition. Currently, several University Departments provide education and training in these fields and conduct relevant research. In most cases, courses related to NP, NA and NE in the graduate level are optional, however several students choose to attend these courses, while many of them are having Diploma Thesis or follow post-graduate studies - mainly PhD studies - in these fields. A post graduate course of great importance is the Inter-University course in Medical Radiation Physics, run through the collaboration of five Universities, the Greek Atomic Energy Commission (GAEC) and the National Centre for Scientific Research (NCSR) "Demokritos". The aim of this course is to provide Medical Physics Experts that staff mainly the medical facilities in the country. GAEC also conducts in Athens the IAEA's regional post-graduate course in "Radiation Protection and Safety of Radiation Sources", in collaboration with three Universities and the NCSR "Demokritos, providing education and training to young professionals aiming to become qualified experts in the field. In this work an overview of education and training provided in Greece in the fields of NP, NA, & NE is discussed.

1. Introduction

Greece is not a nuclear country and it is not foreseen that it will be such, at least in the near future. However, several activities involving the use of nuclear or atomic radiations exist today in the country, as in most developed countries. These activities may be divided into purely research activities, medical, industrial and educational. To facilitate these activities a number of nuclear installations exist in the country. The National Center for Scientific Research "Demokritos" (NCSR-Demokritos) hosts two of the heaviest nuclear installations in the country: (i) a pool type experimental nuclear reactor, currently under refurbishment, which is expected to be operational by the end of 2011 and (ii) a TANDEM accelerator. Several medical installations exist in the country, including Medical LINACS and a Medical Cyclotron for PET radiopharmaceutical production, while others are scheduled. Among the industrial installations of particular importance are: sterilization units and industrial radiography units, while several other non-destructive testing installations exist. Besides these installations, several institutions –

mainly University laboratories – have state of the art infrastructure and apply a variety of nuclear and nuclear related analytical techniques, involving natural and atomic radiations. Most of these activities are focused on radionuclide metrology and issues related to natural, technologically enhanced and artificial radioactivity in the environment, radon related issues etc. All these activities require the existence of experienced scientists in the field of nuclear sciences and highly trained personnel, who will be able to run experimental installations in a safe manner, provide relevant services to the public and private sector and promote the development of nuclear sciences. On the other hand, these installations and laboratories provide the means for a high-level education and training in the field of nuclear sciences, including nuclear physics (NP), nuclear applications (NA) and nuclear engineering (NE).

In Greece, education in the field of nuclear sciences is mainly provided by Universities. Research institutions or other organizations are supporting education; mainly by providing laboratory installations for training, or participating in post-graduate courses, while several students elaborate their Diploma or PhD Thesis in their facilities. Furthermore, a number of students elaborate their Thesis at large Research Centers abroad, such as CERN, in the frame of international collaborations or large research projects. It should be noted that most of the University laboratories providing education in the field of nuclear sciences are members of a network of collaborating laboratories providing support to the GAEC in case of a nuclear emergency. Therefore it is of outmost importance that these laboratories maintain competence in the field of nuclear science and especially in the fields of radionuclide metrology.

2. Education in Nuclear Sciences at undergraduate level

Almost all Greek Universities with Physics and Engineering Departments provide some courses in the undergraduate level, related to nuclear physics and their applications, nuclear engineering and relevant laboratory training. However, these fields are not developed in all Universities at the same level and the relevant courses are not always compulsory. Among Greek Universities, of particular importance due to the extended nuclear sciences related Curriculum are:

- The Kapodistrian University of Athens, the oldest University in Greece established in 1837, with the *Department of Nuclear Physics & Elementary Particles Physics*, under the Faculty of Physics – School of Science, which provides a series of core courses related to nuclear and elementary particle physics and some elective courses related to nuclear technology, medical applications etc. Several students each year elaborate their Diploma Dissertation using the facilities of the *Institute of Material Science,* the *Institute of Nuclear Physics* and the *Institute of Nuclear Technology and Radiation Protection* of NCSR-Demokritos.
- The National Technical University of Athens (NTUA), the oldest Technical University in Greece, established in 1837, has two Departments which are involved in nuclear science education:
    - The *Nuclear Engineering Department*, under the School of Mechanical Engineering, which provides two core courses in nuclear engineering in the Cycle for Energy, and several elective courses covering the fields of: radiation protection, nuclear applications including medical, ionizing radiation metrology, thermo-hydraulics of nuclear reactors and issues related to natural radioactivity, radon, TENORM materials etc. An elective course in nuclear engineering is also provided to the students of the School of Applied Mathematics and Physics Science. The courses provided are accompanied with the relevant laboratory training. Each year 5-6 students elaborate their Diploma Dissertation at the Department facilities.
    - The *Department of Physics,* under the School of Applied Mathematics and Physics Science, which includes two groups: the *Nuclear Physics Group* and the *Experimental High Energy Physics Group*. Tutors from these groups provide courses on nuclear and elementary particle physics and relevant applications, including medical. Each year

several students elaborate their Diploma Dissertation at the Department facilities, while many other elaborate their Diploma Dissertation using the facilities of the *Institute of Material Science,* the *Institute of Nuclear Physics* and the *Institute of Nuclear Technology and Radiation Protection* of NCSR-Demokritos.

- The Aristotle University of Thessaloniki, the largest University in Greece, has two Departments which are involved in nuclear sciences education:
  - The *Section of Nuclear Physics & Elementary Particle Physics*, under the Department of Physics – Faculty of Sciences. With a numerous scientific and teaching personnel, it provides a large number of core and elective courses in nuclear physics, elementary particle physics and astrophysics, as well several elective courses on nuclear physics and issues related to medical applications of radiations, radiation protection, environmental radioactivity, etc.
  - The *Laboratory of Nuclear Engineering*, under the Division of Electrical Energy – School of Electrical and Computer Engineering – Faculty of Engineering. It provides two elective courses related to nuclear reactor theory and technology. Each year 5-6 students elaborate their Diploma Dissertation at the Department facilities.
- The University of Ioannina, with two Sections:
  - The *Atomic & Molecular Physics, Nuclear Physics and High Energy Physics Section*,
  - The *Theoretical Physics Section,*

  with numerous scientific and teaching personnel which provide core courses in modern physics and several elective courses in atomic and nuclear physics, applications, computational & experimental methods in physics etc.
- The University of Thrace, with the *Laboratory of Nuclear Engineering*, under the Section of Energy Systems – Department of Electrical and Computer Engineering. It provides a core course in nuclear engineering and several elective courses in nuclear safety and dosimetry, nuclear technology and applications, including plasma technology.

Courses related to nuclear sciences and applications may also be found in the Curriculum of other Education Institutions in Greece, as for example in the:

- Department of Physics – *Section of Atomic Molecular and Optical Physics* of the University of Crete,
- *Nuclear Engineering Laboratory*, in the Department of Mechanical and Aeronautics of the University of Patras,
- *Department of Physics* in the School of Natural Sciences of the University of Patras,
- *Department of Medical Instruments Technology* of the Technological Educational Institution of Athens.

Undergraduate level courses, related to medical radiation physics and radiation protection are also provided by the Medical Physics Departments, being included in the core Curricula of all Medical and Dental Schools of the Greek Universities.

3. Education in Nuclear Sciences at post-graduate level

Many University Departments or Laboratories, which provide education in the field of nuclear sciences at the undergraduate level, also provide courses at the post-graduate level. In most cases these courses are provided in the context of post-graduate courses with a broader subject. A typical such example is the post graduate course “Physics and Technological Applications”, co-organized at NTUA between: the *Physics Department* and *the Department of Nuclear Engineering* of NTUA and the Institutes *of Material Science* and *Nuclear Physics* of NCSR-Demokritos. However there are also a number of post-graduate courses focused on nuclear sciences.

3.1. The Inter – University Postgraduate Course in Medical – Radiation Physics (IPCMRP)

The Inter – University Postgraduate Course in Medical – Radiation Physics (IPCMRP) is a Course, which aims to a specialized training of physicists in Medical - Radiation Physics. The Course is running under the administration and co-ordination of the Medical School of the Kapodistrian University of Athens, in collaboration with the University of Ioannina, the Aristotle University of Thessaloniki, the University of Crete, the Democritus University of Thrace, the NCSR “Demokritos”, and the Greek Atomic Energy Commission (GAEC).

Depending on the country needs, a total of 10-15 students attend this Course annually. Students attending the Course must a have a Diploma in Physics. The duration of the Course is five semesters and leads to an MSc degree in Medical Radiation Physics. Graduates can participate to the examinations given by the Ministry of Health Committee to obtain the professional license of Medical Radiation Physicist. They may also continue their studies to acquire a PhD degree.

Medical radiation physicists, staff mainly the existing medical facilities in the country, as well as other ionizing radiation facilities acting as:

- Medical Physics Experts in the field of medical exposures according to MED 97/43 EURATOM Directive.
- Qualified Experts according to the BSS 96/29 EURATOM Directive, in the medical field and in the non-medical field, after specialized training or experience.

3.3. The Postgraduate Course on Medical and Radiation Physics of the University of Patras

The principal goal of this Course is similar to that of the IPCMRP. This Course is running on a regular basis by the Faculties of Medicine and Physics of the University of Patras since 1993 and it is attended by 10–15 participants coming from Greece and other European countries. It is a four semesters Course leading to a Master’s Degree, with a Syllabus similar to that of the IPCMRP. The first semester includes introductory to the Medical Physics topics, while the second semester, more specialized ones. The third and fourth semesters include research work and preparation of the Diploma Thesis. Graduates of this Course, having an additional six months on the job training at a Hospital Medical Physics Department, may participate to the examinations given by the Ministry of Health Committee, in order to obtain the professional license of Medical Radiation Physicist. They may also continue their studies to acquire a PhD degree.

3.4 Education Training (E&T) and Specialization coordinated by the Greek Atomic Energy Commission

A significant contribution to education, training and specialization in nuclear sciences in Greece and especially in radiation protection, is that of the Greek Atomic Energy Commission (GAEC), which is the national competent authority for radiation protection and nuclear safety in Greece. According to its statutory law ~~[1]~~, one of its main responsibilities is to provide education and training (E&T) to occupationally exposed workers and to those people involved in the national emergency response plan against nuclear and radiological threats. In order to fulfill the educational needs in radiation protection, GAEC has established partnerships with national and international educational institutions and professional bodies. In particular:

3.4.1 The GAEC E&T activities at National Level

At national level GAEC:

- Provides courses on radiation protection, adapted to the country needs, covering also the needs of occupationally exposed workers in all fields of ionizing radiation applications, such as radiology technologists and industrial radiographers.
- Provides education and training on radiation protection and nuclear security, addressed to law enforcement officers.
- Organizes seminars and workshops in collaboration with professional and scientific institutions on radiation protection, nuclear safety and security and response to radiological/nuclear emergency.
- Operates since 1960 the Hospital Physicists' Post-graduate School.
- Participates and is a major contributor to the Inter-University Post-Graduate Course on Medical Radiation Physics

3.4.2 The GAEC E&T activities at Regional and International Level

The GAEC is the IAEA Regional Training Centre for the European region on "radiation protection and the safety of radiation sources" in the English language, since 2003. In addition, GAEC is the IAEA Regional Training Centre on nuclear/radiological security since 2005.
Within this framework, the GAEC:

- Hosts the Postgraduate Educational Course (PGEC) in "Radiation Protection and Safety of Radiation Sources", co-organized and co-funded by IAEA. The Course is running every two years, with the collaboration of the *Nuclear Engineering Department* of the National Technical University of Athens, the *Medical Physics Department* of the University of Athens and the *Medical Physics Laboratory* of the University of Ioannina. Aim of this 22-week long Course is to meet the educational and initial training requirements of graduate level staff earmarked for positions in radiation protection, including health physics. The Course is conducted in English and is attended by ~20 participants selected by the IAEA.
- Organizes international seminars in specialized fields of radiation protection such as personal dosimetry and authorization and inspection of radiation sources as well as in Nuclear Security.
- Provides on the job training to scientists proposed by the IAEA, in radiation protection issues, such as regulatory control, dosimetry, calibration of ionizing radiation equipment and environmental radioactivity.

4. Conclusions

Though Greece is not a nuclear country, education and training in nuclear sciences is well developed and several institutions provide relevant courses in both the under-graduate and post-graduate level, covering a wide range, from nuclear physics, nuclear engineering, radiation protection, medical and other applications of nuclear technology etc. Collaboration between University Departments, Research Institutions and GAEC is well established and mainly result to post-graduate courses. A small number of post-graduate courses dedicated to nuclear sciences exist in the country, mainly aiming to cover the country needs for qualified experts. Overall, the country needs for specialized personnel in the field of nuclear sciences are fully covered by the education and training provided by Greek Universities in collaboration with existing research centers. Furthermore, GAEC in collaboration with University Departments and Research Institutions provide high level education and training at a national, regional and international level under the auspices of IAEA. The laboratory infrastructure that is available in the country for training in the fields of nuclear sciences is considered adequate and is in many cases state of the art. Any deficiencies in infrastructure are successfully covered by the collaboration between institutions.

INTERACTIVE GRAPHIC SIMULATION: AN ADVANCED METHODOLOGY TO IMPROVE THE TEACHING-LEARNING PROCESS IN NUCLEAR ENGINEERING EDUCATION AND TRAINING

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ABSTRACT

Nowadays, computer simulators are becoming basic tools for education and training in many engineering fields. In the nuclear industry, the role of simulation for training of operators of nuclear power plants is also recognized of the utmost relevance. As an example, the International Atomic Energy Agency sponsors the development of nuclear reactor simulators for education, and arranges the supply of such simulation programs. Aware of this, in 2008 Gas Natural Fenosa, a Spanish gas and electric utility that owns and operate nuclear power plants and promotes university education in the nuclear technology field, provided the Department of Nuclear Engineering of Universidad Politécnica de Madrid with the Interactive Graphic Simulator (IGS) of “José Cabrera” (Zorita) nuclear power plant, an industrial facility whose commercial operation ceased definitively in April 2006. It is a state-of-the-art full-scope real-time simulator that was used for training and qualification of the operators of the plant control room, as well as to understand and analyses the plant dynamics, and to develop, qualify and validate its emergency operating procedures.

The IGS provides the plant responses during normal operation, transients and accident conditions, based on the TRAC code and a set of very illustrative alive screens as well as a set of alarms in a panel similar to the real one at the control room of the nuclear power plant, allowing the real-time automatic and manual normal and emergency operation of the components of the full system. As a result, the IGS plays an important role in the education and training of the students in the nuclear technology field at Universidad Politécnica de Madrid, providing an attractive virtual space that allows them to explore and operate a real nuclear power plant, improving the in-depth understanding of how the whole plant and its safety systems work. On one hand, simulation can attract, motivate and retain students within the nuclear science; on the other hand, simulation emerges as a new way to improve the quality of the nuclear engineering education, creating a more active and participative teaching-learning process, replacing the simple passive memorization of the complex nuclear operational processes by an active and meaningful learning.

This paper presents the work performed at the Department of Nuclear Engineering of Universidad Politécnica de Madrid to turn the IGS professional simulator into a university teaching/learning tool, as follows: first, the methodological aspects of simulation are discussed; then, the developed material to help, guide and evaluate the student during the learning process is presented, and some examples of normal and emergency operation simulation are given; and finally, an assessment of the effectiveness of the simulation based on the lessons learned in the teaching-learning process is discussed. As a conclusion, based on the team-working obtained experience, the advantages, disadvantages and limitations of training simulation for educational purposes in nuclear engineering are presented, as well as the main guidelines to make an interactive graphic simulator an adequate tool for advanced education and training in nuclear engineering.

1. Introduction

The International Atomic Energy Agency (IAEA) sponsors the development of nuclear reactor simulators for education, or arranges the supply of such simulation programs [1]. Aware of this, the Department of Nuclear Engineering of the Universidad Politécnica de Madrid was provided in 2008 with the Interactive Graphical Simulator of the Spanish nuclear power plant *José Cabrera*, whose operation ceased definitively in 2006. According with the IAEA-TECDOC-1411 [2], the simulator is a Graphical Simulator, used for training of main control room personnel, technical support engineers, and operations management. This paper presents all the work performed at the Department to turn the simulator into a teaching/learning tool, to be use in the nuclear engineering studies following guidance found in [3].

First of all, the nuclear power plant of origin was a PWR reactor with only one loop. This makes the installation simpler in order to be used for teaching purposes, that other nuclear plant with 3 or 4 loops.

The simulator provides the real plant responses and the physical behaviour during the normal operation, and simulates several maneuvers, a series of malfunctions, and operational transients, and also allows the training in the emergency procedures under accident situations. With the simulation of these situations the student is trained in the plant behaviour, and in the nuclear and thermohydraulic phenomenology in the nuclear reactor and in the components of the whole plant. For that purposes includes the TRAC-PWR and RELAP5/MOD3.2 codes as the software package, that simulates the whole plant behaviour.

2. Methodology

The Nuclear Engineering Department dedicates two technicians to be responsible of the installation, one for the hardware and equipment, and other for the use of the simulator, and the students assistance. The Department has also the support of the Gas Natural - Union Fenosa company through the assistance of the technician who was the power plant operator trainer in the *José Cabrera* power plant, in order to solve the doubts and problems that may appear during the use of the installation. Also the Tecnatom company that developed the whole installation assist in order to solve punctual hardware and software problems.

A Commission integrated by members of the Nuclear Engineering Department (2 persons) and the Gas Natural - Union Fenosa company (2 persons), has been created to follow the work performed in the Simulator, and make proposals to improve when necessary, the teaching-learning process.

Aware of the advantages that the use of a simulator as SGI can provide for an active and independent training of our students, different material is under preparation for the development of practical classes. The aim is to provide students with the tools necessary to be able to acquire, following an active methodology, scientific knowledge and technology related to the design, safety and economical operation of a nuclear power plant. The intention is to encourage the student giving him a greater role in their learning, by providing a virtual environment that allows operating the plant as if an operator is involved.

In the preparation of this material contribute teachers and technical staff of the Department as well as students who are in different stages of their studies.

Three types of students can be described regarding the use of the simulator:

- Undergraduate students that use the Simulator for the practices period of the topics that are part of the Grade level curricula: *Nuclear Power Plants, Nuclear Technology, and Nuclear Safety.*
- Master degree students that work for a period of 6 months in the Simulator, normally supported by a fellowship of the Consejo de Seguridad Nuclear (CSN, the Spanish nuclear regulatory commission), and develop the Master Final Project in the Simulator. This project provides 15 ECTS (European Credit Transfer System) for the *"Nuclear Science and Technology Master".* Also the Industrial Engineering Master Final Project may be carried out in the Simulator.
- Visiting and collaborating students that spend part of their time learning the use of the simulator and afterwards helping in the development of the material needed for its productive used from the Teaching-Learning objective point of view. The first ones are coming from foreign universities, the second ones are students from the Naval and Industrial Engineering Schools.

The graduate students that use the Simulator should start with the identification and understanding of the existing documentation, and then they may contribute providing more detailed documentation, description of the screens and components, or simulation of different situations. They generate the related documentation with the analysis of the results that have been obtained. Also they may prepare standard and simple practices to be run by the undergraduate students during the teaching-learning period at the grade level studies. Each student has a tutor or director of the project, which analyses the developed material, in order to help, guide and evaluate the student during the learning period.

The students have access to the manuals that the power plant operators have used in the continuous training they have followed [5,6], and the Nuclear Regulatory Commission in Spain demand. The documentation includes the description of the power plant systems, the emergency operation procedures, as well as the description of the Simulator, the initial conditions available, and the malfunctions that may be simulated.

The material that is being prepared for each class or group of classes that constitute a practice for the undergraduate students is divided into three parts according to their purpose in the development of work by the student. These are:

- Practice Manual: objectives and theoretical basis, systems involved in the maneuver and main variables to be monitored, guide implementation of the maneuver, with detailed actions that students must carry out.
- Monitoring material, that the student must complete during the practice: tables for data collection, graphical representation of the temporal evolution of the significant variables, graphical analysis.
- Material self-assessment that the student must complete following the practice: issues related to the development of practical and theoretical foundations.

3. Main results and experience

The standard operational situations that have been prepared for the moment and run by the students are:

- Normal operation in nominal power.
- Nuclear power variations and turbine demand follow.
- Identification of the operational states in the plant: Cold-Zero-Power, Hot-Zero-Power, Hot-Full-Power, Nominal operation.
- Plant start-up, from Cold-Zero-Power to Full-Power.

- Plant down, from Full-Power to Cold-Zero-Power, and evolution during the Zero-Power period.

The simulator also allows the simulation in hypothetical accidents, those which are complex and with a very low probability to happen. This is used in the training, in order to understand the optimal way to drive the plant to an stable and safe situation. For the simulation of the accidents, the best-estimate and realistic codes are used. Codes that have been validated previously. The evolution is done in real time, reason why the student take conscience of the time and the risk of these potential situations, and the high reliability needed in order to limit the global risk.

These accidental and complex situations provide the student the detailed understanding of the head transmission and fluids mechanics, the kinetic reactor behaviour and the coupling among them. These situations are for the moment under testing. They should be carried out by the students when the simpler transients and maneuvers are completely understood .

The accident situations are very extend, and as a sample may be simulated the following:

- Loss of electric feed, with failure of external electrical feed and Diesel Generator.
- Steam generator tube break, with or without the safety injection system.
- Reactor scram signal with failure in the control rod insertion, and success boration.
- Main pump rotor stop, with pressurizer valves opening.
- Small LOCA with safety injection, 0,5” primary circuit break.
- Essential services water loss, and auxiliary feed-water system.
- Components cooling system loss, and auxiliary feed-water system.
- Main steam line break in the auxiliary building, with safety injection system failure.

Until now several projects have been performed by the postgraduate students, under four Collaboration fellowships, and three Master Final Projects, covering the following topics:

- Preparation of the SGI Documentation and User’s Manual (systems descriptions, transient and operational modes, systems identification, screens and alarm panel description)
- Preparation of the SGI Malfuctions Manual (in particular for the Loss of coolant accident)
- Transient analysis due to primary circuit changes (Simulation of Loss of coolant accident in cold leg, user’s guide preparation, analysis of the Emergency Operation Procedures)
- Transient analysis due to malfuctions in the valves (pressurizer shower valve, pressurizer relief valve)
- Optimized Plant Start-up and Initial conditions.
- Optimized Plant down and drive to the cold conditions. Identification of the Xenon peak during the stop period.
- Loss of coolant accident simulation with a guillotine break in the cold leg.

And the practices programmed for the undergraduate students until now have been the following:

- *Nuclear Power Plants*, with 50 students: Nominal operation simulation, and thermal power variation simulation
- *Nuclear Safety* with 40 students: Loss of coolant accident simulation

For these practices the students have the Practice Guide Manual, and as a sample the following documentation is available for the *Nuclear Safety* practice [7] : Practice Manual (description of the practice, systems involved, and variables to follow, and realization guide), Follow-up material (Tables to feel-up, Graphic representations to prepare), and auto-evaluation material (questions to answer).

The students are trained through the simulations in the interpretation of the screens that are showed in the workstations, and the plotted variables and its temporal evolution. The adviser professor examines the results obtained by students in order to assess if the simulation has been effective.

4. Conclusions

The experience obtained so far with the use of the simulator has been very successful. The graduate students involved in the development of the projects, practices and documents related with the simulator show a great interest for the work that they are doing making that the laboratory where the simulator is installed to be busy place. Regarding the undergraduate students, the practices in the simulator encourage them to follow the Nuclear Energy studies in the Engineering Schools, what is very rewarding for the Department professors.

The simulator has proved to be an optimal tool to transfer the knowledge of the physical phenomena that are involved in the nuclear power plants, from the nuclear reactor to the whole set of systems and equipments on a nuclear power plant. It is also a relevant tool for motivation of the students, and to complete the theoretical lessons. This use of the simulator in the learning-teaching process meats also the criteria recommended for the Bologna adapted studies, as it helps to increase the private hands-on work of the student, and allows them to experience the work inside a team, in a practical and real installation.

It should be noticed that this type of simulator is only available in selected universities and Nuclear Engineering Departments in the world, and that it helps to reach the excellence in the nuclear engineering programs studies.

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THE WORLD NUCLEAR UNIVERSITY ACHIEVEMENTS AND PERSPECTIVES

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ABSTRACT

The WNU was inaugurated in 2003 in a London ceremony commemorating the 50th anniversary of President Eisenhower's historic Atoms for Peace initiative, the visionary proposal that gave birth to the IAEA. That UN agency is one of the four world organizations known as the WNU's "Founding Supporters". Within the UN system, the WNU is recognized as a "Partnership for Sustainable Development" by the UN Commission on Sustainable Development (CSD). Other founding supporters are the NEA (OCDE), WANO and the World Nuclear Association, WNA.

A non-profit corporation, the WNU pursues its educational and leadership-building mission through programmes organized by the WNU Coordinating Centre (WNUCC) in London. These cooperative activities are designed to harness the strengths of partnership members in pursuit of shared purposes.

WNU programmes are unique and intended to complement existing institutions of nuclear learning by filling unmet educational and training needs on the international, global level. These programmes are designed to capitalize on the WNU's strength as a partnership that draws on support from industry, governments and academia.

To date, WNU programmes have focused on building nuclear leadership and providing orientation on the main issues that affect the global nuclear industry today. As of March 2011, over 2,500 nuclear professionals and students from over 60 countries have participated in such programmes. This paper will focus on the main existing programmes, the yearly 6-weeks long Summer Institute now in its seventh edition and held in Oxford (UK), the new school of radioisotopes held for the first time in Korea in 2010, the One-week courses - "Key Issues in the World Nuclear Industry Today" held around the world mostly in emerging countries that are considering the pacific use of Nuclear Energy and the school of Uranium Production, focused on the Front End of the Fuel Cycle.

1. Introduction

The World Nuclear University (WNU) is a global partnership committed to enhancing . international education and leadership in the peaceful applications of nuclear science and technology. The central elements of the WNU partnership are threefold:

1. Firstly, the global organizations of the nuclear industry, the World Nuclear Association (WNA) and World Association of Nuclear Operators (WANO).
2. Secondly, the prime inter-governmental nuclear agencies, the International Atomic Energy Agency (IAEA) and the Nuclear Energy Agency of the Organization for Economic Cooperation and Development (OECD-NEA).
3. And finally, leading institutions of nuclear learning in some thirty countries around the world.

The WNU was inaugurated in 2003 in a London ceremony commemorating the 50th anniversary of President Eisenhower's historic Atoms for Peace initiative, the visionary proposal that gave birth to the IAEA. That UN agency is one of the four world organizations known as the WNU's "Founding Supporters". Within the UN system, the WNU is recognized as a "Partnership for Sustainable Development" by the UN Commission on Sustainable Development (CSD).

2. Status

A non-profit corporation, the WNU pursues its educational and leadership-building mission through programs organized by the WNU Coordinating Centre (WNUCC) in London. These cooperative activities are designed to harness the strengths of partnership members in pursuit of shared purposes. Operationally, the WNU is a public-private partnership.

On the public side, the WNUCC's multinational secretariat is composed mainly of nuclear professionals supplied by nuclear companies and governments; the IAEA further assists with financial support for certain WNU activities.

On the private side, the nuclear industry provides administrative, logistical and financial support via WNA, the World Nuclear Association: www.world-nuclear.org

3. WNU Summer Institute

The annual 6-week WNU Summer Institute (WNU-SI) is one manifestation of this global partnership. The Summer Institute is open to about 100 WNU Fellows each year from around the world, selected from among promising nuclear professionals who demonstrate strong leadership potential. At the Summer Institute, WNU fellows are educated in a broad spectrum of nuclear energy issues, engage in team-building and leadership exercises, and develop a network that will support them during their careers.

The inaugural WNU-SI was held in USA in 2005. The 2006 Summer Institute took place in Sweden and France. Korea hosted the third WNU-SI in 2007, Canada the fourth in 2008, the United Kingdom and France the fifth in 2009. From 2009, the WNU-SI is held annually at the world famous college, Christ Church at Oxford University, UK.

Figure 1: 2010 Summer Institute session in Christ Church College, Oxford, UK

With the completion of the 2010 Summer Institute in Oxford, there are now 566 Fellows from 65 countries who have completed this World Nuclear University initiative, who are now part of an expanding global network of future leaders in the nuclear profession.
The WNU-SI curriculum is designed to provide cutting edge presentations on the full range of topics relevant to the future of nuclear technology. Presentations generally take place in the mornings, with topics falling into the following categories:

- Global Setting, including:
  - energy supply and demand,
  - global warming and climate change, nuclear

- technology in sustainable development, lessons in
    - public acceptance, and key political issues and trends;
- International Regimes, including:
    - nuclear safety,
    - radiological protection,
    - non-proliferation and security,
    - waste management,
    - transport,
    - nuclear law,
    - and global greenhouse emissions control;
- Leadership and Management, including:
    - nuclear safety culture,
    - different views of leadership,
    - interactions with present and past leaders of the Industry,
    - frequent interactions with mentors setting examples, counselling and giving personalized advices;
- Technology Innovation, including:
    - next-generation reactors,
    - advanced fuel cycle,
    - waste management,
    - hydrogen production, desalination, advanced battery power;
- Nuclear Industry Operations, including:
    - Industry economics,
    - knowledge management,
    - fuel market,
    - comparative risk assessment,
    - and operational excellence.

In the afternoons, the selected participants or "Fellows" break into working groups composed of around ten people. A Fellow is likely to be assigned to three of these groups during the WNU-SI, allowing him/her to work closely with a large number of people. Each group is overseen by a Mentor, one of a number of experienced academic or industry leaders that participate throughout the WNU-SI. During working group sessions, Fellows engage in reviews of the morning's presentations, preparation of responses to challenging case studies assigned by faculty during the morning lectures, presenting information about themselves, and nuclear programs in their countries and preparation of an in-depth presentation on a topic key to the future of the nuclear industry.

Figure 2: Working groups allow for cooperative work without borders

Besides the leadership development activities, the Summer Institute also consists of presentations from "Invited Leaders", people who have made notable contributions to the nuclear industry. Unlike the faculty members responsible for implementing the curriculum, Invited Leaders have the freedom to choose their message. In practice, they are likely to discuss their organization’s current and future work, the major challenges they see unfolding in their area of interest and experience and in the field as a whole, what they think will be required of future leaders and describing the personal characteristics and skills one would look for in a future leader, and how to prepare for assuming responsibility.

Finally, fellows engage in a one-week field trip to a variety of nuclear and industrial facilities.

4. One Week Course

These events, called "Key Issues in the World Nuclear Industry Today" are designed to enhance the knowledge of mostly younger people about how nuclear science and technology are applied in the world today, while encouraging an expansive view of where it is likely to go in the future. International experts lecture on a wide range of topics with the aim of offering practical knowledge, a global perspective and an exciting vision of the future, which should stimulate interest amongst attendees in pursuing further careers in this area.

Participants are masters-level university students in nuclear science and engineering, staff at nuclear research centres, professionals in the local nuclear industry and equivalent government employees, including regulators and energy planners. They are generally people with some background knowledge of nuclear and maybe some specialist knowledge in one or more areas. The overall aim of the course is to give attendees a comprehensive knowledge of the key issues in the world industry today, to enable them to place their own current role into perspective while also opening their eyes to the opportunities of the future. A related objective is to encourage different groups involved in nuclear within the country to communicate more closely with each other, to the benefit of all.

Figure 3: One week course in Argentina March 2011

The faculty presents overviews of a full range of nuclear related topics, from uranium exploration to plant decommissioning, also covering the myriad of issues in between which bear on them. The curriculum is adapted to satisfy the needs of the particular country but the intention is to leave attendees with a full appreciation of the key issues.

Each course consists of 20-25 modules, each of 60-90 minutes teaching and discussion time. Teaching is generally in English, but translation services have been used on some courses. 4-5 modules are taught each day, with breaks between each for refreshments and lunch.

So far, 20 courses have been organized around the world, following the launch at Tsinghua University, Beijing in July 2007. Locations are chosen where there is significant local interest in nuclear, e.g. China, Korea, Latin America and South Africa, but limited ability of people to travel large distances to more international training courses. Success has been achieved in that over 2,000 students have so far attended the courses. Local academic and business institutions host the events, attracting attendees mainly from the host country, but invitations are also extended to young people in nearby countries with close academic, political or cultural ties.

5. School on radioisotopes

The annual WNU School on Radioisotopes (RI School), inaugurated in Seoul, Republic of Korea in May-June 2010, is a training program aimed at younger professionals currently involved in, or soon to be engaged in, managerial roles in RI production and application.

Through their participation, selected applicants develop a broad understanding of RI production methods, RI applications in a variety of areas, as well as related topics. They furthermore gain familiarity with the main challenges encountered by practitioners within the field. Above all, the RI School is a unique opportunity to network and exchange ideas with fellow professionals from around the world.

The RI School's three-week program features lectures from some of the world's foremost leaders in the area of radioisotope production and application; small group work, where participants tackle case studies and develop proposals for resolving some of the major issues within the field; technical visits to RI-related sites; team-building and recreational activities.

6. School of Uranium Production

The International Training Centre (ITC) of the World Nuclear University – the School of Uranium Production (WNU-SUP) was established in 2006 and it is run by the Czech uranium production company DIAMO under the auspices of WNU in London. It is locating at Stráž pod Ralskem, near Prague.

WNU-SUP develops and presents teaching programs focused on professional training in all aspects of uranium production, i.e. from surveying, exploration, extraction by different mining methods and ore processing through to environmental and employee health protection to the decommissioning and rehabilitation of mining areas following the termination of extraction.

Activities are mostly based on cooperation with IAEA in Vienna, which, in terms of technical cooperation, conducts project work with developing countries, nominates participants for long-term training and organizes specialized scientific visits. Short and long term courses are available in different topics: Uranium Deposits Exploration, Uranium in-situ leaching technology, Alkaline Uranium Ore Milling, Tailings Pond Remediation, Legislative Framework of Mining and Processing, Decommissioning and Rehabilitation.

The high professional level of DIAMO staff and the extensive practical experience of its operators are used to good effect. Such courses are not only taught by experts from DIAMO, but also by foreign lecturers from mining operators and independent consultants in other scientific spheres – geology, hydrogeology, geo-mechanics, chemical engineering, radiation protection, environmental protection, etc. – as required by the focus of individual courses.

7. Nuclear English Courses

In today's globalizing nuclear industry, proficiency in English is an essential asset for nuclear professionals. WNU's intensive English-language courses help learners prepare for the English-speaking environment, enabling day-to-day communication with colleagues, the writing of effective reports, and participation at conferences.

The textbook Nuclear English (WNU Press) provides an important reference throughout the course.

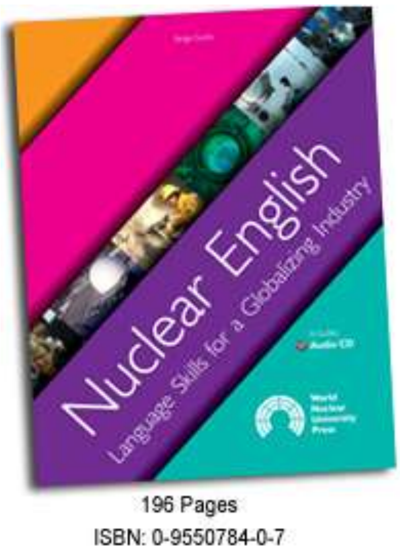

Figure 4: Nuclear English Textbook and Audio CD

8. Further reference:

For further information, please visit the WNU website,

http://www.world-nuclear-university.org

TRAINING IN THE NUCLEAR FIELD AT THE CONSERVATOIRE NATIONAL DES ARTS ET MÉTIERS

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ABSTRACT

This article is devoted to a presentation of the training in the nuclear field at the Conservatoire National des Arts et Métiers. The latter is a public multidisciplinary university that provides lifelong professional training.

1. Introduction

In France, training in various disciplines is divided in two levels: first stage and professional. In the nuclear field, because of the wide industrial applications, the professional training is very developed. Both private, i.e. provided by industries or other independent , and public training, i.e. provided by universities and “Ecoles d”ingénieur”, are available. The Cnam is a public university.
This article is divided in three parts. In the first one, the Cnam and its main tasks are presented. In the second part, the training in nuclear science and technology are presented and detailed, in terms of pedagogical contents and practical details of training. In the third part, future development are discussed, before drawing our conclusions.

2. The Cnam

The Cnam - Conservatoire national des arts et métiers - is a public multidisciplinary university, mainly dedicated to lifelong professional training. The Cnam is an unique French institution of long-standing and deep scientific tradition. It is supervised by the French Ministry of Higher Education and Research.

The Cnam is established in 28 French regions and 23 countries. Nearly 100,000 people enroll each year in our professional and management development programs. 11,000 students are currently studying for undergraduate, graduate or doctoral degrees. Among the 2,000 people employed by the Cnam, 500 are full-time professors or researchers. 7,000 associate professors or professionals teach at the Cnam. Each year we hold on average 350 national and international conferences.
The Cnam has been entrusted with 3 closely interconnected missions:

a) Lifelong education

The Cnam enables students :

- to improve their skills
- to keep ahead developments in each field
- to follow a complement training
- to get a degree or recognized qualifications.

It is divided into two schools, with about 10 specialties:

- SITI School (Sciences Industrielles et Technologies de l'Information)
- MS School (Management et société)

The first one groups together industrial sciences and techniques, computer sciences, electronics, mathematics, while the second one comprises, economics, management and human and social sciences applied to firms.
At Cnam, training programs are open to everyone: employees, freelance workers or job-seekers, irrespective of qualifications, and at any work experience in their career; nearly 100,000 people enrol each year in our professional training courses. The teaching schedule at the Cnam is compatible with a professional activity. Each person has the opportunity to construct a "made-to-measure" program and to train at a pace suited to personal circumstances. The Cnam offers a wide range of training programs, from undergraduate to graduate through to doctoral levels. The Cnam delivers either professional certificates based on French national standards (RNCP), or universally recognized degrees in line with the Bologna scheme (Bachelor, Master and Doctorate) in various disciplines.
To meet the growing demand of people wishing to study independently, at home or in the workplace, the Cnam has significantly increased the number of open and distance learning solutions (internet, e-training, etc.). Currently, there are 50% of distance-learning programs on offer and 1 in 5 students is trained by distance-learning programs.
The Cnam has significant expertise in the validation of personal attainments and experience. In order to meet the many requests it receives, the Cnam has set up a network of 70 VAE (validation of life and work experience, from its French acronym) advisors, 8 panels per year and a distance-learning guidance website.
Finally, the Cnam provides companies, organizations and local government agencies with training programs designed to help fulfil the needs of their employees and therefore improve their competitiveness and efficiency. Among other services, it offers companies and organizations 550 training programs covering various fields of business, engineering and human sciences. The Cnam can also provide companies with "made-to-measure" training programs adapted to their training environment and/or to their human resources strategies.

b) Research and Innovation

As in the case of the other higher education institutions, the Cnam is also committed to undertake research projects. The Cnam hosts 25 recognized research teams and 290 teaching researchers, assisted by research engineers and technicians. It offers 36 doctoral programs and currently has around 390 doctoral students enrolled in a variety of disciplines, strongly oriented toward technological research. Patents, tests, license transfers, service development, innovative processes, technology transfer, business incubation... The research purpose of the Cnam is to meet the expectations of business. In this respect, The Cnam research teams work with major research bodies and Universities. They collaborate closely with businesses and get involved in groups, associations and networks of excellence corresponding to their major themes. Research and development at the Cnam favours a policy of well-identified research niches, corresponding to the expectations of major professional sectors. The projects, developed within partnerships, bring businesses operational solutions. Each year the Cnam registers more than 100 research contracts with industrial companies.

c) Scientific and technological knowledge

As a major scientific institution, the Cnam has a mission to raise awareness of scientific and technological culture and to give everyone an access to knowledge through its rich and varied resources. One distinctive characteristics of the Cnam is its museum: The “Musée des arts et métiers”. As a significant focus on scientific and technical heritage, it plays an important role in the dissemination of scientific and technical culture in France. With 6,000 m^2 of permanent public exhibition space, the museum makes the genius of innovation and the historical development of science and technology available to all, covering 7 themes:

scientific instruments, materials, construction, communication, transport, energy, and mechanics.
This unique collection spans 250 years of technical innovation and also includes 15,000 technical drawings and more than 80,000 exhibits - one of the most famous being Foucault's pendulum. The museum also has reserved collections that are available to specialists and researchers.
The Musée des arts et métiers welcomes around 200,000 people each year, including 40,000 school children.

The Cnam has also a documentary network which consists of a reference collection devoted to science and technology. It contains:

- 447,000 volumes,
- 37,000 dissertations and doctoral theses,
- more than 4,500 periodicals,
- 900 videos, 180 CDRoms and 30 encyclopaedias.

In the last few years, the documentary network has increased its presence with the creation of its On-line library, which now includes more than 300,000 digitized pages. Each year the online Library receives 26,000 visits with 10.5 million pages downloaded.

3. Training in the nuclear field at Cnam

a) Introduction

Training in the nuclear field has been available at the Cnam since 1948; it includes two options: nuclear reactor technology and radiation protection. Four different diplomas are delivered: a Cnam's certification, called "certificat de compétences" and three universally recognized degrees: a license, a RNCP title, and an engineering degree.
The contents of the training courses have been defined in close collaboration with professionals in the field, in order to provide the required competences. They are organized in units of 6 European credits (ECTS), which are capitalized over time. Ten units are specialized in the nuclear field. Each student has the opportunity to train at his own pace depending on personal and professional circumstances. In order to adapt to the wide range of activities in the nuclear field, the Cnam offers the opportunity to construct an individual "made-to-measure" training program by validating complementary units in chemistry, materials technology, metrology, occupational health....
Professional experience is totally integrated in the training program. Some credits are awarded through an official recognition of professional experience.

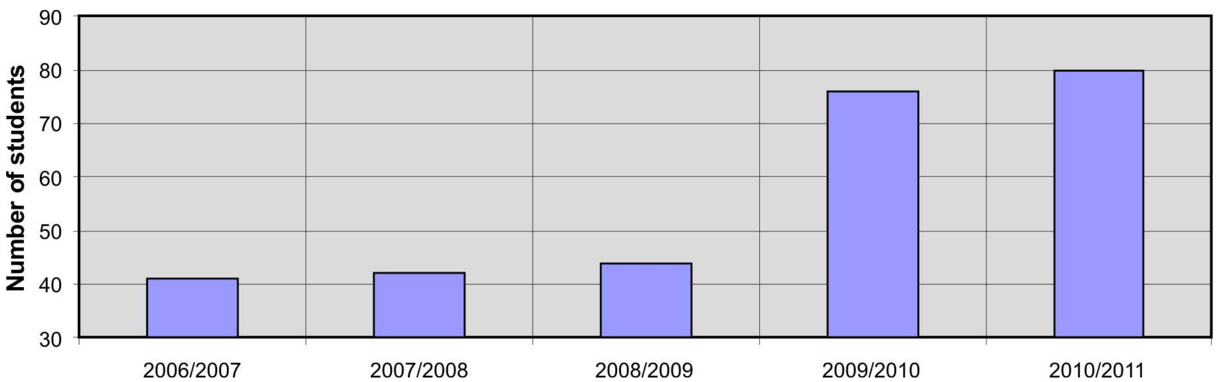

Figure 1 – Time evolution of the number of students attending the nuclear training at Cnam.

Since two years, all the theoretical nuclear units have been made available in e-learning mode, which meets well the needs of professionals (Fig. 1). The Cnam has developed an internet platform Plei@d, which is accessible as an internet site. This site is also translated in some language like English, Arabic, Spanish, etc.

The platform Plei@d offers a lot of services like chat, video-conference, mail, open forum…
In nuclear training we have used this internet site to diffuse theoretical lessons and exercises. Both a video of the professor teaching and a written file can be downloaded by the student. For all 3 or 4 lessons a MCQ is proposed, aimed at helping the students to understand the theoretical parts, and a brief overview of all lessons is given. Once a month, a meeting with all the students is held. It can be attended either in person or via the Internet, in real time or delayed. The final written test is always held in one of Cnam centres in France. The only training course which is not in e-learning is the practical one. It is held either on Saturdays, during a longer interval, or during the days of a single week.

b) The different diplomas:

- The home's diploma: "certificate de competences"

This course is dedicated to persons who have validated a diploma and want to gain solid theoretical nuclear knowledge. It lasts about one year, but could be reduced to a few months, and has a volume of 36 units of ECTS (30 nuclear units and 6 units of project management). It is proposed to generalist engineers in professional re-orientation.

- The licence:

This course allows the persons in professional situation to continue their formation to Master diploma. They must have validated a diploma of 2 years of studies after Baccalauréat or 120 units of training in science and industrial techniques with the system of the validation of the knowledge (VAE or VES from the French acronym). The global volume of this diploma is 180 ECTS of which 18 nuclear units. The professional experience should be validated by a written report which should show the experience of the candidate and his knowledge of the subjects of the licence.

- The RNCP title:

This diploma is a professional certificate based on French national standards. It can be taken as the first year of the master and has a global volume of 120 ECTS (72 ECTS of training, of which 42 are nuclear ETCS).
Two years of professional experience in the nuclear domain are required. Alternatively, one can achieve the diploma if he has spent three years working in another domain, plus a work experience of three months in the nuclear domain. It is worth 48 ECTS.
Who holds this title is recognized in the nuclear industry as a fully qualified technician.

- The engineering degree

The global volume of this diploma is 180 ECTS, of which 48 are nuclear and have two orientations: technology of nuclear reactors and radiation protection. Three years of professional experience, of which two years in nuclear domain, is required and count for 33 ECTS. Finally, a work experience of at least 9 months in the nuclear domain, with a written report, is required. This work experience is discussed during an oral presentation in front of a panel of professors and professionals. This counts for 45 ECTS credits. Everyone can construct an individual training program by validating 24 ECTS complementary units in other disciplines.

The courses are organized in a preparation and a specialization cycle and cover all the nuclear disciplines: fundamental nuclear physics, radioactivity, radiation detection and measurement, neutron physics, nuclear reactor theory, nuclear fuel cycle, radiation

protection, thermo hydraulics. It is the only training course in France which has this level in all nuclear domains.
The competences specificity of one engineer Cnam consists in the duality between the long and rich professional experience and a high level scientific and technical training.

4. Evolution of the training in the nuclear field

Considering all the request from the industrials and the leader place of the Cnam in the professional training sector, it appears that the Cnam will be a main actor in the development of the adult's professional training. Nowadays, the nuclear applications cover many fields of expertise. Until now, the nuclear training at Cnam has been focused only on the electro-nuclear industry. In the near future, we plan to create, a professional training centre in the nuclear field. It will be aimed at:
- developing training courses in the other fields of nuclear applications like medical domain, materials for nuclear applications, dismantling nuclear facilities…;
- creating training courses for subcontractors which meet the requirements of nuclear safety authorities;
- providing support to large groups in the nuclear industry which need to outsource parts of their internal training program;
- developing some training courses on an international scale.

5. Conclusion

In this article we present the professional training provided by the Cnam and, in particular, we discuss the training in the nuclear field. The four available professional courses are aimed at matching the needs of adult students. The most popular course allows to gain a nuclear engineer degree. It is divided into two modules: technology of nuclear reactors and radiation protection. It is the only training course in France which has this level in all nuclear domains.
In the future, we plan to widen the range of nuclear training in all fields of nuclear applications and on an international scale, in cooperation with the nuclear industry.

EXPERIENCE ACQUIRED DURING THE FIRST THREE YEARS OF THE SWISS MASTER IN NUCLEAR ENGINEERING

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ABSTRACT

Since 2008, a Master of Science program in Nuclear Engineering (NE) has been running in Switzerland, thanks to the combined efforts of the country's key players in nuclear teaching and research, viz. the Swiss Federal Institutes of Technology at Lausanne (EPFL) and at Zurich (ETHZ), the Paul Scherrer Institute (PSI) at Villigen and the Swiss Nuclear Utilities (swiss*nuclear*). The first two student batches, viz. those that started in 2008 and 2009, have followed a 3-semester (90 ECTS-credits) curriculum. Starting with the third batch of students, who joined in September 2010, the curriculum has been upgraded to 4 semesters (120 ECTS), making the Swiss program fully compatible with other European universities under the Bologna system. The present paper presents the experience acquired to date with the three different batches of students who have participated in the program

1. Introduction

The key national players in nuclear teaching and research in Switzerland are the Swiss Federal Institutes of Technology at Lausanne (EPFL) and at Zurich (ETHZ), the Paul Scherrer Institute (PSI) at Villigen and the Swiss Nuclear Utilities (swiss*nuclear*). Since 2008, these four institutions have been pooling resources in running a Master of Science degree in Nuclear Engineering (NE), the first – and currently only – common degree offered jointly by EPFL and ETHZ [1]. The present paper focuses on the experience acquired to date with the three different batches of students who have participated in the program.

2. The 3-semester curriculum and the first two student batches

The first two student batches, viz. those that started in 2008 and 2009, have followed a 3-semester (90 ECTS-credits) curriculum. Thereby, the first two semesters have been spent on course work, the final semester being devoted to an 8-week (minimum) industrial internship followed by a 17-week research project.

With the close collaboration between EPFL, ETHZ, PSI and swiss*nuclear* forming the basis for the program, there has been a corresponding sharing of responsibilities in its implementation. Thus, the students have spent their first semester entirely at EPFL and the second at ETHZ. The third semester has been mainly based at PSI, where the Master's research project is carried out, this being normally preceded by the mentioned 8-week internship in industry. The multi-campus nature of the NE Master – though advantageous in several ways – does impose an extra financial burden on the students due to the necessary changes of accommodation. In order to render the program "costs neutral" in this context (relative to the other, single-campus programs), supplementary funds have been made available to each student through the ETH-Domain's Competence Centre Energy and Mobility (CCEM-CH).

The foundations of the NE Master – the teaching language for which is English – are laid by the *core courses*. In the 3-semester curriculum, these have comprised seven compulsory courses (Section 2.1) and five so-called core electives (Section 2.2). Collectively, they are designed to provide the students with the basic knowledge needed to meet the goals of the program, viz.

- Provide in-depth knowledge on the fundamentals and technology of harnessing nuclear fission for safe and reliable energy supply.
- Provide complementary knowledge on nuclear fusion.
- Provide knowledge on nuclear techniques in medicine, research and industry.
- Provide a view on the complete nuclear energy conversion system, i.e. the entire fuel cycle from uranium mining to the back-end.
- Underline the positioning of nuclear energy as part of a sustainable, global energy mix.

2.1 Compulsory Courses

The seven compulsory courses have accounted for 28 of the 90 ECTS of the 3-semester curriculum, clearance of each one of them being necessary for obtaining the Master's degree. Four of the courses – Neutronics, Reactor Experiments, Reactor Technology, and Nuclear Fuels and Materials – have been conducted at EPFL, partly because this is the university assuming the leading role for physics and materials related subjects. The other three compulsory courses – Nuclear Safety, Special Topics in Reactor Physics, and Nuclear Energy Systems (centred on the various aspects of the nuclear fuel cycle) – have been conducted at ETHZ, the university with the leading role for thermal-hydraulics and engineering related topics.

A specific difficulty posed by the above split in location of the individual compulsory courses has been that the Reactor Experiments course clearly needs to follow the theoretical Neutronics course. However, the key installation needed for the Reactor Experiments course is the CROCUS teaching reactor on the EPFL campus (see Fig. 1). With the students being physically present at Lausanne only during the first semester, it is at this time that they can easy access the CROCUS reactor. The solution which has been found is that, unlike the other NE courses, which are spread regularly over the 14 weeks of the corresponding semester, the Neutronics and Reactor Experiments courses are offered in a "compressed" form, each over 7 weeks, with twice the usual weekly hours. Thus, the Neutronics course takes place during the first half of the first semester, with the Reactor Experiments course following during the second half.

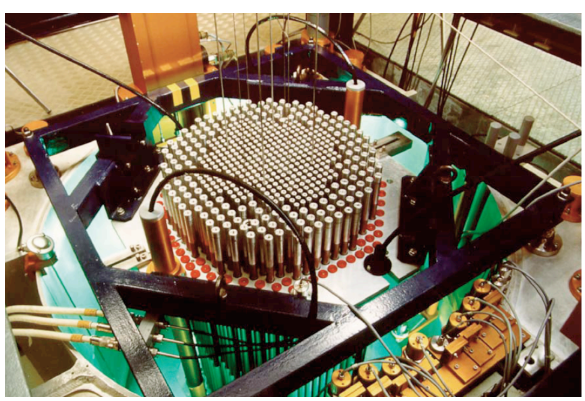

Figure 1. Top view of the CROCUS reactor at EPFL

2.2 Core Electives

The five core electives – amounting to a total of 20 ECTS – have been chosen by the students from out of the following three "tracks":

- Track A: Energy Systems
- Track B: Physics and Materials
- Track C: Thermal-hydraulics

The tracks are meant to guide the students, in a structured manner, towards the main educational orientations offered by the program. To a certain extent, they have also served as an aid in the selection of tutors. Tracks, however, are not equivalent to different specializations, i.e. the choice of a track is not noted on the final degree. In fact, the students are free to choose courses from more than a single track. They make their choices, however, in consultation with their respective tutor, and are fully aware of the orientation implied in each case.

Four core electives have been offered in each track. In Track A (Energy Systems), these have been Advanced Fossil and Renewable Energy Systems, Hydraulic Turbomachines, Probabilistic Safety Analysis and Risk Management for Critical Energy Infrastructure, and Renewable Energy Technologies II. In Track B (Physics and Materials), the four offered courses have been Nuclear Fusion and Plasma Physics, Introduction to Particle Accelerators, Radioisotope and Radiation Applications, and Advanced Topics in Nuclear Reactor Materials. Finally in Track C (Thermal-hydraulics), the four courses have been Instability and Turbulence, Two-Phase Flows and Heat Transfer, Multi-Phase Thermal Fluid Dynamics, and Advanced CFD Methods.

2.3 Students' research

Apart from the core courses, students in the 3-semester curriculum have taken two "free" elective courses, had an 8-week (minimum) industrial internship, and carried out research in the form of a semester project and a 17-week Master's thesis. The semester project, aimed at introducing the students to R&D in nuclear engineering, has been carried out during the second semester, in the form of a full day spent each week (i.e. 14 days in total) in one of the laboratories of the Nuclear Energy and Safety (NES) Research Department at PSI.

Apart from the scientific and technical knowledge acquired during the first semester, the basis for each student's choice of R&D topic has been the information provided during a 1-day technical visit to PSI. Organized towards the end of the first semester, this has served to introduce the students not only to the key experimental facilities available at PSI for nuclear R&D, but also to the principal research projects being pursued by the different NES laboratories. Each on-going R&D activity presented has included an indication of related Master's thesis topics which could be made available. This aspect has constituted an important criterion for the student's choice of research laboratory to work in, since the semester project is usually considered as a preparatory phase for the Maser's thesis itself. As illustration, Table 1 lists the different R&D activities presented to the students during their PSI visit in December 2009. Also indicated, in each case, is the corresponding responsible NES laboratory.

The NE Master's thesis work – conducted during the final semester – is essentially aimed at enhancing the student's capability to work independently towards the solution of a theoretical and/or experimental R&D problem in nuclear engineering. As mentioned, the Master's thesis is usually linked directly to the semester project carried out earlier and involves a workload of 17 weeks, full-time. As in the case of the semester project, the work is carried out under the supervision of a senior NES scientist, under the mentorship of a responsible professor (who may or may not be the student's tutor). Upon successful completion of the thesis – including an oral examination in the presence of an external expert – the student is awarded 30 ECTS.

Table 1. List of PSI-NES presentations made to the 2009 batch of NE Master students

No.	*R&D Activity*	*Responsible Laboratory*
1.	Experimental Reactor Physics	Reactor Physics and Systems Behaviour
2.	LWR Core & Transient Analysis	
3.	Gen. IV Fast Reactor Studies	
4.	Thermal-hydraulic Phenomena	Thermal-hydraulics
5.	Severe Accident Phenomena	
6.	Nuclear Fuels R&D	Nuclear Materials
7.	Reactor Component Safety	
8.	High Temperature Materials	
9.	Analytical Techniques (Fuels)	Hot Lab
10.	Waste Management	Waste Management
11.	Technology Assessment	Energy Systems
12.	Risk & Human Reliability	
13.	Materials for Nuclear Fusion	Centre for Research in Plasma Physics (EPFL)
14.	Magnets for Nuclear Fusion	

For the first NE Master batch, viz. the students who started the program in September 2008, presentations of the various R&D activities at PSI were made in December 2008. These were very similar to those listed in Table 1. On the basis of the Master thesis topics proposed at the time, semester projects were carried out as preparatory work and, in most cases, the students retained the basic topics they had selected for their Master's research. Table 2 gives examples of the research topics pursued by the 2008 students' batch.

Table 2. Examples of research topics for the Master's thesis (2008 students' batch)

No.	*Research Topic*
1.	SCWR[a] design validation via PROTEUS experimental data
2.	Improved Monte Carlo calculations of RPV[b] fluence
3.	Analysis of PHENIX pre-shutdown tests
4.	Feasibility study for neutron tomography of 2-phase flows
5.	Validation of CFD[c] modelling results
6.	Modelling of reactor containment flows
7.	An isotopic dilution technique for fission gas analysis
8.	LCA[d] analysis of waste disposal and CO_2 sequestration

[a] super-critical water reactor; [b] reactor pressure vessel; [c] computational fluid dynamics; [d] life cycle analysis

2.4 The students and their feedback

Twelve students have made up the first NE Master batch (2008), with 4 from Switzerland, 3 from the USA, and 1 each from Argentina, China, France, Greece and Lebanon. Six of these students are Bachelor degree holders in Physics, 3 have their Bachelors in Mechanical Engineering, 2 in Nuclear Engineering and 1 in electronics. Eleven of the 12 students cleared the required 50 ECTS during their 1st and 2nd semesters, before embarking on the 25-week (minimum) period associated with the industrial internship (at least 8 weeks) and the Master's thesis project at PSI (17 weeks).

In the second (2009) NE Master batch, there are 13 students, i.e. a very similar number to that in the first. Seven of these students stem from Switzerland, and there is 1 from each of the following countries: Canada, Colombia, Greece, Lithuania, the UK and the USA. The distribution in terms of Bachelor degrees is 5 in Physics, 3 in Mechanical Engineering, 2 in Chemical Engineering, and 1 each in General Science, Information Technology and Marine Engineering.

It is seen, from the above data for the first two batches, that students stemming from Swiss universities have accounted for only about 45% of the NE Master students to date. As such, the program – although naturally addressing Switzerland's needs – is clearly to be viewed in an international context, e.g. that of the Bologna Agreement. This is further evidenced by the fact that, during the 2009 Autumn Semester at Lausanne, there were 3 exchange students in Nuclear Engineering, 2 from the Technical University of Barcelona (Spain) and 1 from the Polytechnical University of Turin (Italy).

Also to be noted quite clearly is the wide variation in the technical background of the students. The most common types of Bachelor degrees of the joining students have been Physics (~45%) and Mechanical Engineering (~25%).

The convocation of the first NE Master batch was held in October 2010. All the 10 students who obtained their degrees on this occasion have either found employment in industry or have embarked upon doctoral research. Of the 14 students who started in the 2009 batch, 12 have completed their course work, as also their industrial internships, and are currently pursuing their Master research projects at PSI.

The general feedback from the NE Master students of the first two batches has been very positive. For the vast majority, attending classes in two different universities, with their different cultures, has been an enriching experience. In spite of the variation in their technical backgrounds at the Bachelor level, the students of both batches have found most of the courses both interesting and challenging. Moreover, the wide range of R&D topics made available for the Master's research at PSI has been seen as a noteworthy strength of the program.

3. The upgraded (4-semester) curriculum and the third student batch

The NE Master was conceived as a 90 ECTS (3 semester) program shortly after the transition to the Bologna system, at a time when most Swiss university degrees were being transformed from a 4½-year single degree (diploma) to a 3-year Bachelor, followed by a 1½-year Master. The experience of the first 2 years of running the NE program has shown that (a) the course work, concentrated into 2 semesters, is rather intense and (b) the allotted 25-week period for the industrial internship plus the Master's thesis is a bit too short. Deliberations during 2009-2010, at both EPFL and ETHZ, culminated in a decision to introduce an additional semester, i.e. to upgrade the curriculum to a 120 ECTS program. This change – which also increases the conformity of the program with Bologna as a 3 + 2-year system – is discussed below.

3.1 The new curriculum

As indicated, the most important element of the new NE Master curriculum – launched in September 2010 – is the introduction of an additional semester. This is effectively the third semester, which is to be spent largely at PSI and is meant to be used for:

- The semester project (shifted from the second semester to the third)
- Four core courses offered as block courses, i.e. in modular form (see Table 3)
- The industrial internship, which will be more formalized with 8 ECTS associated with it.

The other curriculum changes are relatively minor. They correspond to an "exchange" of semesters between the courses Nuclear Fuels and Materials, and Radioisotope and Radiation Applications, and an increase in the free electives from 6 to 12 ECTS. Clearly, the Master's thesis at PSI – with its unchanged 30-ECTS weightage and 17-week duration – gets moved to the fourth semester.

The shifting of the semester project from the second to the third semester implies that the presentation of R&D activities at PSI is to be made to the students towards the end of the second semester, rather than at the end of the first. This is clearly an advantageous feature from the point of view that, at the time of having to select their research topic, the students will have two semesters of course work behind them, rather than just one.

Among the third-semester core courses (Table 3), Advanced Topics in Nuclear Reactor Materials already exists in the current curriculum (see Section 2.2). The other 3 courses are really new. Radiobiology and Radiation Protection as an additional, separate compulsory course fills a need that has been felt for some time, the number of hours currently consecrated to this important subject matter within Nuclear Safety being deemed rather insufficient. Nuclear Computations Lab, as a 3-ECTS core elective, will complement the compulsory courses Special Topics in Reactor Physics and Nuclear Safety, in that it will focus on the practical usage of large computer codes for NPP neutronics and multi-physics transient analysis. Finally, Beyond-Design-Basis Safety will allow a more detailed presentation of thermal-hydraulics phenomena during severe accidents, a subject matter that has been treated rather briefly under Nuclear Safety in the 3-semester curriculum.

Table 3. NE core (block) courses in the 3rd semester of the new 120 ECTS curriculum

No.	*Course*	*Responsible Univ.*	*Course Type*	*Held at*	*ECTS*
1	Radiobiology and Radiation Protection	ETHZ	Compulsory (new)	PSI	4
2	Adv. Topics in Nucl. Reactor Materials	EPFL	Core Elective	PSI	4
3	Nuclear Computations Lab	EPFL	Core Elective (new)	PSI	3
4	Beyond-Design-Basis Safety	ETHZ	Core Elective (new)	PSI	3
				Total:	14

The upgrading of the NE Master curriculum from 3 to 4 semesters offers full compatibility with other major Nuclear Engineering programs in Europe. With EPFL and ETHZ both being members of the European Nuclear Education Network (ENEN) [2], the prospects for international collaborations in nuclear education will certainly be enhanced, not only in terms of partner universities but also in the context of industrial organisations such as EDF and Areva. This should help to stabilise the number of students joining the program every year, a batch strength of ~20 being the currently targeted figure for the medium term.

A specific feature of the new curriculum, which will promote student exchange in a somewhat different manner, is that the course work during the third semester – as mentioned – will be carried out in terms of block courses, i.e. in modular fashion (rather than spread over 14 weeks as in the case of the first two semesters). This should attract students from abroad who wish to obtain ECTS credits corresponding to only one or more of these courses, since they will be able to do so with a relatively short stay in Switzerland.

3.2 The 2010 student batch

The third (2010) batch, i.e. the first one to embark upon the new 4-semester curriculum, has 15 students. As in the case of the first two batches, students stemming from abroad are in the majority, and there is a large variation in technical background. Thus, 3 of the students stem from Switzerland, 3 are from India, 2 from Canada, and 1 each from China, the Czech Republic, Germany, Indonesia, Poland, Singapore and the Ukraine. The distribution in terms of Bachelor degrees is 4 in Physics, 3 in Mechanical Engineering, 2 each in Chemical Engineering and Materials Science, and 1 each in Chemistry, Civil Engineering, Mathematics and Nuclear Engineering.

The advantages of the new NE-Master curriculum have already started to be felt by the students, e.g. the improved overall structure of the program. As mentioned, one of the modifications made has been the exchange of semesters between the courses Nuclear Fuels and Materials, and Radioisotope and Radiation Applications. This has been particularly beneficial for Reactor Experiments – a course which most of the students have termed "crucial" for their Nuclear Engineering education. With Radioisotope and Radiation Applications now taught in parallel with Neutronics, i.e. during the first half of the first semester, the students are provided with an even more solid theoretical background for the Reactor Experiments course in the second half of the semester, particularly in the context of experiments related to radiation measurements.

4. Conclusions

As the first-ever common degree to be offered by EPFL and ETHZ, the Swiss NE Master represents a unique collaboration not only between the two national technical universities, but also with PSI, as national research centre, and the Swiss nuclear utilities, responsible for generation of ~40% of the country's electricity. Although, in the first instance, the program addresses Switzerland's needs for young specialists in the nuclear field, it is clearly to be viewed in an international context. This is reflected in the composition of the first three batches of the NE Master, with more than half the students stemming from outside the country.

The present paper – while describing the main features of the program – has presented the experience acquired to date, as also the important change which has been made starting with the third student batch, viz. with effect from September 2010. This is the upgrading of the curriculum from 90 to 120 ECTS, i.e. from 3 to 4 semesters. It is expected that this will not only strengthen the program as a whole, but also further enhance its compatibility with other major Nuclear Engineering programs in Europe, thus increasing the prospects for international collaborations.

Acknowledgements

The authors would like to acknowledge the invaluable contributions of the many persons from EPFL, ETHZ, PSI and the Swiss nuclear industry, who have contributed to the success of the NE Master's program.

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UTILISATION OF VR-1 REACTOR FOR NUCLEAR EDUCATION AND TRAINING

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ABSTRACT

The paper presents utilisation of the VR-1 reactor for nuclear education and training at national and international level.
The VR-1 reactor has been operated by the Czech Technical University in Prague since December 1990. The reactor is a pool-type light water reactor based on low enriched uranium fuel (19.7 wt% of ^{235}U) with maximum thermal power 1 kW and for short time period up to 5 kW. The moderator of neutrons is light water, which is also used as a reflector, biological shielding, and coolant. The pool disposition of the reactor facilitates access to the core, setting and removing of various experimental samples and detectors, easy and safe handling of fuel assemblies.
The reactor has been used very efficiently especially for education and training of university students and NPP's specialists for more than 20 years. The VR-1 reactor is utilised within various national and international frameworks such as the Czech Nuclear Education Network (CENEN), the European Nuclear Education Network (ENEN) and also the Eastern European Research Reactor Initiative (EERRI). The reactor is well prepared for high-standard education and training not only by the experimental facility itself but also by incessant development of training methods and improvement of education practices. The education experiments can be combined into training courses attended by students according to their study specialization and knowledge level. The training programme is focused on reactor and neutron physics, dosimetry, nuclear safety, and control of nuclear installations. Approximately 200 university students undergo training at the VR-1 reactor every year. Their stay at the reactor site means an enormous benefit for their study process.

1. Introduction

The training reactor VR-1 was put into operation in December 1990 at the Department of Nuclear Reactors of the Faculty of Nuclear Sciences and Physical Engineering, Czech Technical University in Prague. The reactor is used in education of students from technological universities, in R&D, in the education and training of specialists in the nuclear industry and other institutions, and finally, in promotional activities within the field of nuclear power.
The education and training is oriented towards the reactor and neutron physics, dosimetry, nuclear safety, and control of nuclear installations. R&D activities are limited by reactor thermal power and neutron flux, but it is possible to perform studies requiring reactor core free from fission products and dynamic experiments with negligible thermal feedback. Research at the reactor is mainly focused on the preparation and testing of new educational methodologies, investigation of reactor lattice parameters, reactor dynamics studies, research in the field of control equipment, neutron detector calibration, etc.
The VR-1 reactor is utilised within various national and international frameworks. The utilisation of VR-1 reactor at national level takes place within the Czech Nuclear Education Network (CENEN). The international co-operation is based mainly on activities realised

within the European Nuclear Education Network (ENEN) and the Eastern European Research Reactor Initiative (EERRI).

2. Basic Technical Parameters of VR-1 Reactor

The VR-1 Training Reactor (see Fig 1) is a pool-type light-water zero-power reactor operated with low-enriched uranium fuel with estimated maximum thermal power 1 kW and for short time period up to 5 kW. The reactor core is installed in a stainless steel vessel designated as H01. Similar vessel H02 serves for manipulations and temporal storage of fuel assemblies. These two vessels can be connected and fuel assemblies can be moved from reactor core to the temporal storage in vessel H02 under water providing sufficient shielding.
Moderation of neutrons is realized by light demineralised water, which is also used as a reflector, biological shielding, and coolant. Heat is removed from the core by natural convection. The pool disposition of the reactor facilitates access to the core, setting and removing of various experimental samples and detectors, easy and safe handling of fuel assemblies.

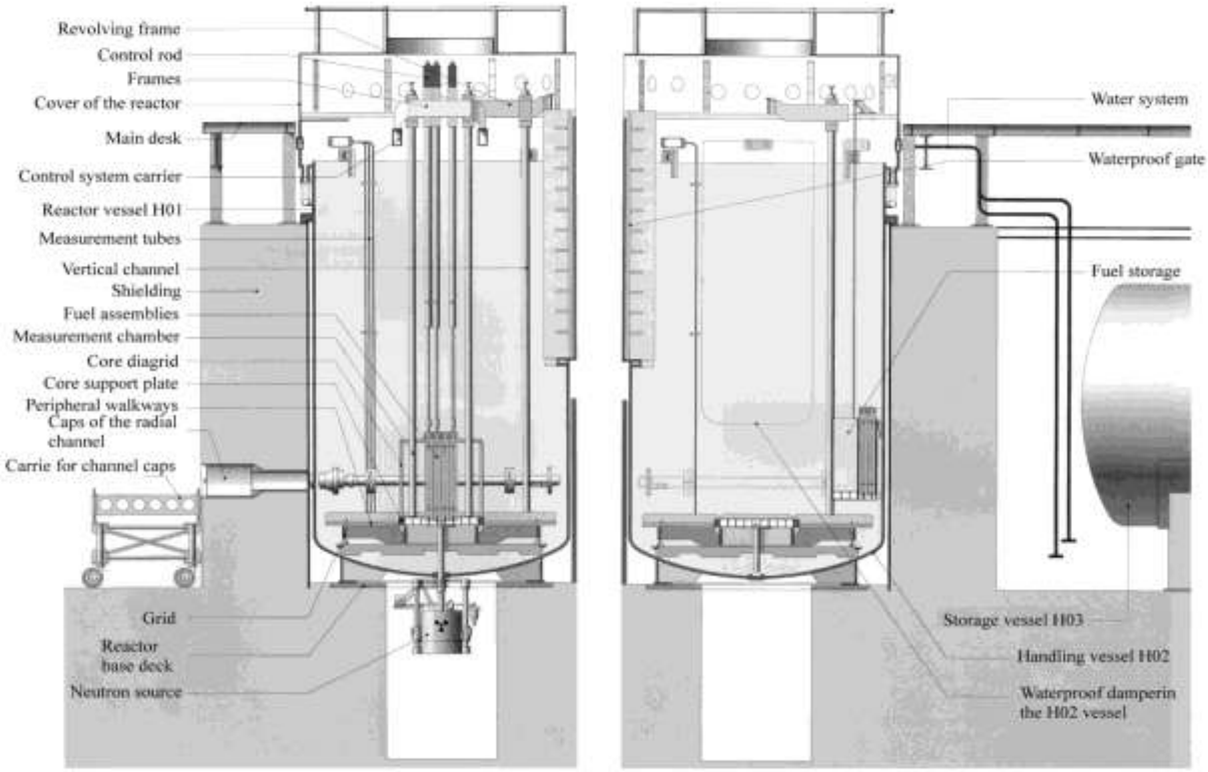

Fig 1: Vertical cross-section through the VR-1 reactor

Reactor was successfully converted from high-enriched uranium (fuel type IRT-3M, enrichment: 36 wt% ^{235}U) to low-enriched uranium (fuel type IRT-4M, enrichment: 19.7 wt% ^{235}U) in 2005 [1].
The reactor core can consist from 17 to 21 fuel assemblies IRT-4M in a square lattice, depending on the geometric arrangement and kind of experiments to be performed in the reactor. High variability of the core configurations is achieved by possibility to include in the core fuel dummies (empty position in the core grid filled with water) or assemblies containing graphite or beryllium.
Maximum 7 cadmium absorbing rods can be installed in the core. They serve for the reactor control and safe shutdown. Construction of all the rods is identical, but they differ in their functions (safety, compensation or control) according to the connection to the control and safety system.

Digital control equipment consists from control and safety system, signalling system, connecting system, and neutron source control. The Am-Be neutron source is used to start up the reactor. It ensures a sufficiently high response at the output of the power measuring channels from the deepest sub-criticalities, and thus guarantees a reliable reactor control during the reactor start-up.
The reactor is equipped with several experimental devices [2]; e.g. horizontal, radial and tangential channels used to take out a neutron beam, reactivity oscillator for dynamics study and bubble boiling simulator. Basic technical properties of the VR-1 reactor are summarised in Tab 1.

Thermal Power	1 kW, 5 kW for short time period
Neutron Flux	2-3x10^9 n/cm^2.s
Fuel type	IRT-4M, ^{235}U enrichment 19,75 wt% (imported from Russia)
Reactor Vessels (pools)	made from stainless steel vessel diameter 2 300 mm vessel height 4 720 mm wall thickness 15 mm
Reactor Shielding	above core: water layer 3 000 mm side: water layer about 850 mm + concrete 950 mm
Temperature	20 °C (according to the ambient temperature)
Core Cooling	natural convection
Pressure	atmospheric
Control Rods	5-7 control rods: 3 safety (shut-down) rods, 0-2 experimental rods (according to the core configuration), 2 control rods
Operating Power Measurement	four wide-range non-compensated fission chambers
Independent power Protection	four pulse corona boron counters
Neutron Source	Am-Be, 185 GBq, emission rate of 1.1x10^7 s^{-1}

Tab 1: Basic reactor characteristics

3. Education and Training at the VR-1 Reactor

The educational purpose of the VR-1 reactor was taken into account already in the very beginning of the designing phase of its operation. It is a zero-power reactor with excellent characteristics for providing service in training of students from technological universities and specialist from Nuclear Power Plants. Training is focused on areas such as reactor physics, neutronics, dosimetry, reactor operation, nuclear safety and I&C systems.
Depending on the curriculum and orientation of individual users, the training at the reactor is performed in a regular weekly schedule or in a form of batch courses two to five days long. The specific content of the courses is compiled according to the requirements of the respective users. The courses and experiments are available in three levels:

- demonstration;
- basic;
- advanced.

The demonstration level is intended for basic understanding of physical phenomenon, which is applied during the experiment and participants are rather passive observers.
In the basic level, participants actively take part in the experiment, and independently evaluate acquired data according to the preceding theoretical lecture.

The advanced level is designed for in-depth study of the issue and requires a deeper theoretical knowledge of participants and their active participation in the preparation of measurements, during the experiment and interpretation of acquired values. A chosen phenomenon or process is often analysed using several different approaches or conditions.
Currently, over 25 experiments are prepared at the reactor [3]. The most frequent experiments are the following:

- basics of neutron detection using gas detectors;
- determination of gas detectors dead time;
- analysis of neutron detectors properties for reactor I&C;
- measurement of delayed neutrons;
- determination of neutron flux distribution by tiny gas detectors,
- determination of neutron flux distribution by activation detectors (Au foils, Cu wires);
- reactivity measurements (e. g., Rod Drop, Source Jerk, Positive Period);
- control rods calibration (e. g., by Inverse Count Rate);
- analysis of various materials impacts on reactivity;
- criticality approaching and critical experiment;
- study of nuclear reactor dynamics;
- start-up, controlling and operation of a nuclear reactor;
- bubble boiling simulation and its impact on reactivity;
- short-time instrumental neutron activation analysis.

The less frequent specialized experiments are aimed at determination of kinetic characteristics (e.g. neutron lifetime, effective delayed neutron fraction), selected analytical methods for the environmental protection or extended experimental courses of digital control systems.

4. Utilisation of VR-1 Reactor within National and International Cooperation

The VR-1 reactor is as a specialized training facility of the Ministry of Education, Youth and Sports. In addition to students of the Czech Technical University in Prague, it is open to students from other universities in the Czech Republic. Majority of reactor training for students from the Czech universities takes place within the scope of the CENEN framework (see Fig 2). Every year 150-200 students from Czech universities undergo specialized training at the VR-1 reactor. Student's stay at reactor site means an enormous benefit for their study process.
The reactor is frequently used for training of NPP's specialists as well. The users are both from Czech NPPs (Dukovany and Temelin) and Slovak NPPs (Jaslovske Bohunice and Mochovce). Approximately 5 courses for NPP's staff take place at VR-1 reactor every year.
Integral part of reactor utilisation is education and training of students coming from abroad. There is a close individual cooperation with institutions from Germany (Fachhochschulle Aachen), Slovakia (Slovak University of Technology in Bratislava), Sweden (KTH Royal Institute of Technology in Stockholm) and Austria (Atominstitut TU Vienna). Education for foreign students is also organized within the scope of ENEN. Approximately 40 foreign students take part in courses at the VR-1 reactor each year.

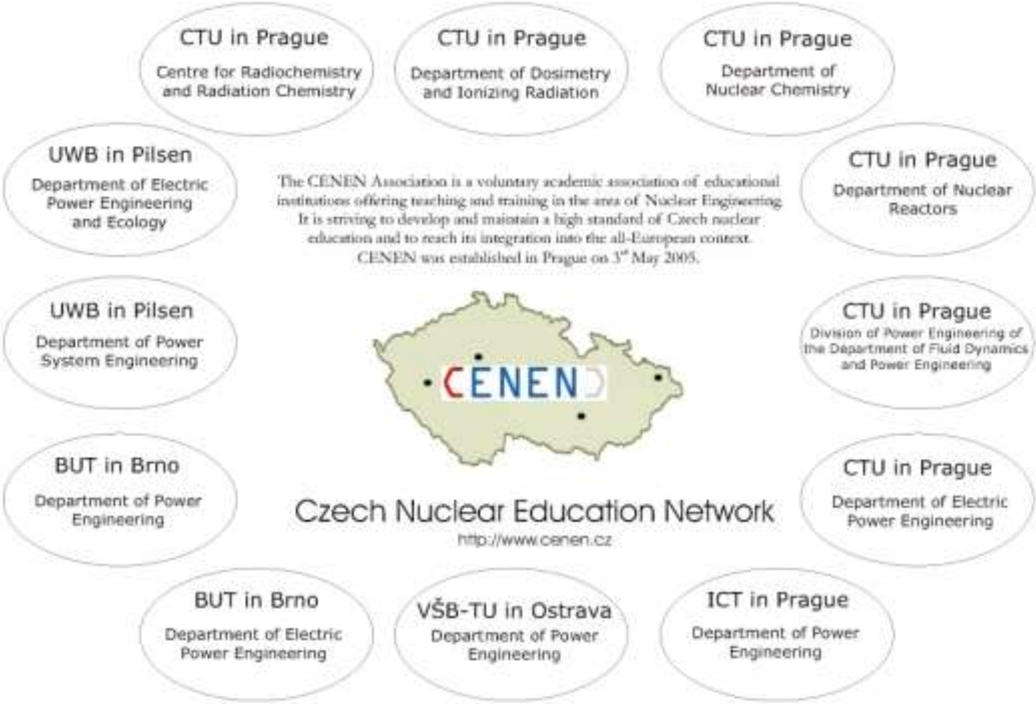

Fig 2: Schematic drawing of cooperation within the CENEN framework

There are also several courses organised at the VR-1 reactor in cooperation with IAEA. These include activities related to EERRI. EERRI was established in 2008 and covers 8 research reactors (see Fig 3) from 6 European countries as an example of regional co-operation between research reactors. Soon after its establishment, the EERRI in collaboration with IAEA organised and successfully carried out the first group education and training course dedicated for the Members States aiming to build their first research reactor.
To this date, four training courses were successfully completed. Two of them took place at the VR-1 training rector in cooperation with the Atominstitut of the Vienna University of Technology, Austria, Josef Stefan Institute from Ljubljana, Slovenia and Nuclear Research Institute in Rez, Czech Republic. A specialized educational program consisting of theoretical lectures and practical experiments at the reactors is prepared for participants of this course.

Fig 3: Research reactors utilised within EERRI
(LWR-15 and VR-1– Czech Republic, JSI – Slovenia, ATI – Austria, INR – Romania, BRR and TUB – HUNGARY, Maria – Poland)

Another important part of the VR-1 reactor mission is to be open to the public and provide unbiased information regarding operation of research and power nuclear reactors. High-school or university students as well as general public have the possibility to visit the reactor. Programme of visit is didactic; containing a lecture regarding the physical background of a reactor operation, a site visit, and demonstration of reactor operation. More than 1000 visitors come to the VR-1 reactor every year.

5. Conclusions

The VR-1 reactor has been used very efficiently for nuclear education and training of university students and NPP's specialists for more than 20 years. The utilisation of VR-1 reactor at national level takes place within the CENEN organization. The international co-operation is based mainly on activities realised within ENEN, IAEA and EERRI. The operator and main user of the VR-1 reactor is the Czech Technical University in Prague; another five Czech universities participate in its use. The co-operation with foreign universities is frequent as well. Every year, approximately 250 undergraduate students undergo training at VR-1 Reactor. Further training courses are provided for specialists from Czech and Slovak NPPs. There are five special courses per year. Every year more than 1000 visitors from the general public come to the VR-1 reactor within informational and promotional activities.

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